WEST AFRICAN CACAO RESEARCH INSTITUTE

ANNUAL REPORT

April, 1949 to March, 1950

14MAY1952

TAFO, GOLD COAST

Published on behalf of the West African Cacao Research Institute by the Crown Agents for the Colonies, 4, Millbank, London, S.W.1.

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WEST AFRICAN CACAO RESEARCH INSTITUTE.

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J. West, Esq.	Director of Cacao Research, West African Cacao Research Institute.

WEST AFRICAN CACAO RESEARCH INSTITUTE.

SENIOR STAFF LIST AS AT 31st MARCH, 1950.

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Deputy Director ...	Vacant.
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Division of Agronomy	R. J. Benstead, N.D.A., C.D.A. R.Wickens,B.A.(Cantab.),Dip.Agric.(Cantab.), D.T.A.(Trin.).
Secretary	G. H. Neal, F.R.S.A., F.I.P.A.
Construction Engineer	Major C. Alderson, D.S.O., E.D., B.Sc., M.Inst.M. and C.E.

WEST AFRICAN CACAO RESEARCH INSTITUTE.
ANNUAL REPORT : 1st APRIL, 1949 TO 31st MARCH, 1950.

I. POLICY AND ORGANIZATION.

Senior Staff Changes.

On 20th December, 1949, Mr. O. J. Voelcker left the Gold Coast to take up his new appointment as Director of Agriculture, Federation of Malaya. His departure marks the conclusion of a five year period during which he was largely instrumental in guiding and developing the Institute from its inception to its present established position as a research centre. The results which the Institute has achieved owe their inspiration to the leadership, appreciation of scientific research and wide knowledge of cacao which Mr. Voelcker possessed. His summary of the work of the Institute, written in simple language, is to be published as a bulletin.

The post of Deputy Director is at the moment vacant but it is hoped that Mr. A. Pickles, Senior Entomologist, Agricultural Department, Nigeria, will shortly be appointed.

As stated in the previous Annual Report Mr. A. F. Posnette, Senior Pathologist, had accepted secondment to East Malling Research Station, and he left the Gold Coast on 11th April, 1949.

The Institute lost the services of Mr. E. W. Alther, who was unfortunately invalided home.

Mr. J. F. Archibald was appointed as Temporary Horticulturist and Mr. H. R. Mapother joined the staff as Insecticidal Chemist on secondment from the Agricultural Research Council.

Managing Committee.

The Managing Committee met at Tafo in December, 1949, and in February, 1950. Apart from matters of administration and finance, the Committee continued to take a keen interest in the work of the Institute, and the beneficial effect on progress of this interest cannot be too greatly emphasised.

Tours.

In addition to the normal tours of W.A.C.R.I. Staff, the Director paid visits to Nigeria in February and in March, 1950, to discuss cacao research and disease control with members of the Agricultural Department.

Visitors.

Numerous visits have been paid to the Institute by members of the Agricultural Departments of the Gold Coast and Nigeria. Such visits are invaluable in maintaining close co-operation and in facilitating the rapid exchange of information and ideas.

In December, 1949, His Excellency the Governor of the Gold Coast paid a visit to see the work of the Institute on swollen shoot control and cacao rehabilitation. The following week members of the Legislative Council paid a similar visit prior to the consideration of legislation for the compulsory treatment of farms affected by swollen shoot disease.

Visitors from other countries have also been welcomed at the Institute, including cacao planters from the Belgian Congo, scientists from French Togoland, economists and representatives of the Colonial Office from the United Kingdom, scientists, members of F.A.O. and representatives of the cacao manufacturing interests from the U.S.A., and the Principal of the Imperial College of Tropical Agriculture, Trinidad.

Scientific Assistance.

The Institute continues to receive generous assistance from individuals and research organizations in other parts of the world. Through the work of the Commonwealth Bureau of Biological Control, Canada, the first releases have been effected of parasites and predators of mealybugs from California. Rothamsted Experimental Station kindly allowed Mr. B. M. Church to pay an extended visit to the Institute to advise on statistical problems and undertook to provide a one year course of training in statistics for a nominee of the Institute. Mention must also be made of the continued assistance received from the Colonial Insecticides Committee and the British Food Manufacturing Industries Research Association.

During the year the Institute provided facilities to the representative of the Lister Todd Engineering Corporation for extensive tests of the Tifa machine in its cacao plots. The Senior Plant Pathologist, Department of Agriculture, Federation of Malaya, visited Tafo to study cacao diseases, and the Institute in co-operation with the Agricultural Department assisted him to collect 200 pods of West African Amelonado cacao for trial introduction in Malaya. As a result of an agreement reached at the Colonial Office the Institute is providing facilities for Messrs. Pest Control Limited to carry out a series of experiments with systemic insecticides at Tafo, a novel joint venture between a research institute and a commercial firm.

London Cocoa Conference.

This conference was convened in London in August–September, 1949, by the Cocoa, Chocolate and Confectionery Alliance Limited. The Institute was represented by Mr. O. J. Voelcker and Mr. A. F. Posnette. As in the past the conference provided the opportunity for an exchange of views and information among those interested in the production and manufacture of cacao.

Public Relations.

As was mentioned in the previous Annual Report it was felt that the Institute had achieved results of great practical importance and that these results should be given wide publicity. The Public Relations Department of the Gold Coast now issues to the local press a series of articles entitled " Farmers Corner ", based on information supplied by the Institute, the Agricultural Department and the Gold Coast Cocoa Marketing Board.

DEMONSTRATIONS.

Although the demonstrations at W.A.C.R.I., which are organized by the Department of Agriculture, reach a more limited public than do the articles in the press, they are probably at least as effective. Parties of farmers and school children, from all parts of the Gold Coast, visit W.A.C.R.I. every day and are able to see for themselves that diseases and pests of cacao can be controlled, that cacao farms can be maintained and rehabilitated successfully, and that improved varieties of cacao are being produced for the benefit of farmers.

CONSTRUCTION.

Progress has been continued in the building programme during the past year. The schedule, brought up to date from last year's Annual Report, is as follows :—

	Approved.	Completed.	Building.
Administrative Block	1	1	—
JUNIOR STAFF :			
Four-Roomed Houses	10	10	—
Three-Roomed Houses	50	50	—
Two-Roomed Double Units ...	62	62	—
Recreation Hall	1	—	—
SENIOR STAFF :			
Bungalows	13	11	2

For the pipe-borne water supply, the dam across the valley has been completed, and much of the service pipe line has been laid. Continued delays in the receipt of material for the filtration plant have been experienced, but two houses for staff and a store have been completed at the site.

The Gold Coast Electricity Department has kept abreast of the building programme with the installation of electrical wiring, but there have been delays in the extensions to the power plant.

SWOLLEN SHOOT DISEASE.

Experiments on the control of swollen shoot by cutting out and replanting have been continued. Evidence is accumulating to the effect that the amount of cutting out required during subsequent retreatments depends on the amount of infection present at initial treatment, as the following examples illustrate.

1. Where the original infection was slight ; control, over an eleven year period, has reduced the tree population by only 7 per cent. (W.A.C.R.I. Old Station).

2. Where the original infection was heavy, *i.e.*, 32 per cent. of the tree population, control including the removal of contact trees over four years, has reduced the population by a further 25 per cent. (W.A.C.R.I. Square Mile).

3. Where the original infection was heavy, *i.e.*, 39 per cent. and the farm small, control confined to the removal of diseased trees without contacts over five years has reduced the population by a further 36 per cent. (Koransang 20 acres).

4. Where the original infection was heavy, *i.e.*, 31 per cent., with no control over four years the disease has reduced the population by a further 57 per cent. (8¼ acre farm, W.A.C.R.I.).

All these four examples are taken from Tafo or Koransang, both in the area of mass infection. In areas where infection was on a much smaller scale, *i.e.*, in Kwaben and Kwahu in 1941, control by cutting out both trees showing symptoms and apparently healthy contact trees was much more effective. Out of 21 outbreaks treated in Kwahu, 17 showed no further infection two years after treatment. In Kwaben 69 outbreaks were treated and the disease stopped in 59 of them.

In the area of mass infection it would seem more economical to remove all the cacao trees in blocks where the initial rate of infection is high. This was done in the four W.A.C.R.I. sub-stations at Akwadum, Adonkwanta, Nankese and Kukua, which total 90 acres, before the land was replanted with cacao in 1945. So far reinfection of the young cacao has been confined to the boundaries adjoining untreated farms which have been devastated by swollen shoot.

At Tafo and in the Institute's sub-stations, young cacao, planted after cutting out, has continued to do well. The protection of these plants from the ravages of capsid bugs called Akate by the use of a D.D.T. emulsion has been amply demonstrated.

Improved Seed Distribution.

In the Annual Report for 1948–49, mention was made of the superiority of certain introduced varieties over the common West African type as regards early bearing. One of these is particularly outstanding and efforts are being made to introduce clonal material of the parents of this selection for use in plant breeding work.

During the past year some 75,000 basket seedlings and seeds were issued to the Gold Coast Agricultural Department and 5,000 seeds to the Nigerian Agricultural Department. The object is to establish blocks on land under the control of the Departments. Should these progenies of the Upper Amazons fulfil the promise of the parent trees and should the beans be acceptable commercially these blocks will provide for the demonstration of methods of cacao re-establishment as well as seed supplies for issue to farmers.

Black Pod Disease.

Results obtained during the past season have substantiated the claim that Black Pod disease can be controlled by regular harvesting. The frequency of harvesting must be adjusted according to the weather conditions, since wet weather favours the spread of the disease through the light crop and into the developing main crop. At Tafo it was found that for an area of some 60 acres of cacao it was actually cheaper to employ one gang of men solely for weekly harvesting and fermenting, and by this means the losses from pod disease were held in check despite the wet weather. Weekly harvesting proved as effective as weekly spraying with fungicides on the basis of good ripe beans harvested, in the spraying experiments. The Nigerian method of fermenting in baskets was found to be effective in dealing with the small quantities of beans which weekly harvesting involves at the beginning and end of the cropping season.

Acknowledgment.

As in the previous Annual Report, the technical sections of the present Report have been prepared by the officers concerned and the Director gratefully acknowledges their authorship.

II. VIRUS RESEARCH.

Viruses and Virus Diseases of Cacao.

New Viruses.

Two new viruses have been noted during the year and both are of interest because of distinctive symptom expressions. The first is fairly common in the Peki area of the Volta River district of the Gold Coast, where a few outbreaks, now up to a 100 acres in extent, have been known since 1942. Leaf symptoms are not produced by this virus, the only symptoms being swelling of the twigs, chupons and roots ; chupon swellings are rare and twig swellings, though often conspicuous, are usually of sporadic or infrequent occurrence on infected trees. In one outbreak reputed to cover 100 acres, only a proportion of the trees has been marked as infected but it is certain, from the difficulty of detecting symptoms, that many diseased trees have so far escaped attention. Some trees infected for at least six years appeared healthy and no case of a severe reaction was encountered.

The second virus was discovered in excellent cacao country near Bompata in Ashanti Akim. Other outbreak areas of this or a similar virus are said to occur near Obogu, Banso, Bankame, Asuboa, Dampong, Tomento and Agrafi, towns and villages which are scattered through about 300 square miles in Ashanti Akim. One very striking feature of the outbreaks seen near Bompata was their small size ; individual outbreaks, though never more than a few hundred yards apart, did not themselves consist of more than three dozen trees. With this virus swellings are unknown. Leaf symptoms are borne on occasional flushes and occur usually as a close yellow banding of scattered portions of the secondary and tertiary veins ; symptom-bearing leaves are not reduced

in size. Infected trees did not seem to be in any way debilitated compared with apparently healthy neighbours.

Besides the Peki virus, there are only two others known which do not normally produce leaf symptoms ; outbreaks of one occur near Bisa in the Volta River district and those of the other near Agogo in Ashanti Akim. It is unlikely that the three viruses are closely related. The Bompata virus resembles the Kpeve (Togoland), Asalu (Nigeria) and Alaparun (Nigeria) viruses in not having stem symptoms but its leaf symptoms are quite different from those of the others.

Inter-Relationships of Viruses.

The method of the protection test for close virus relationship has been described and some results cited in previous annual reports. Twenty-nine of the 40 West African cacao viruses or important strains in the W.A.C.R.I. collection have been included in various protection test combinations, of which almost 160 have been or are still being carried out. Mutual antagonism between viruses has been demonstrated in very few instances. It would appear that close relationship (as evidenced by cross protection) does not exist between any two viruses with very different symptoms or which, though perhaps having similar symptoms, occur in widely separated areas ; the degree of virulence, in itself, carries no indication of relationship. Two notable exceptions to the second of the above-mentioned generalizations are the Konongo (Ashanti Akim) and Kongodia (Eastern Ivory Coast) viruses, both of which are incapable of producing symptoms in seedlings already infected with a mild strain of the New Juaben virus (virus 1A).

The viruses of the Wiawso district in the Western Province of the Gold Coast are notable for their multiplicity (Ann. Rep., 1947–48, p. 11). Outbreaks of at least nine symptomatologically distinct viruses occur within a few miles of the town and, in some cacao farms, outbreaks of two different viruses have been found. A complex protection test with seven of the Wiawso viruses is being carried out and the indication to date is that they are not immunologically related. This result might seem anomalous in view of the natural close geographical proximity of the viruses and the fact that their symptoms, though different, show certain similarities. It is believed, however, that the basic apparent anomaly is not so much their non-relationship as their multiplicity, a matter for which an explanation is suggested in the discussion of *Cola chlamydantha* K. Schum., commonly an alternative host of these viruses (pp. 43–44).

Field Experiments and Demonstrations with Cacao Viruses.

Five field experiments or demonstrations have been continued by the Pathology Division throughout the year. They are :—

1. Demonstration of rate of spread of severe virus 1A and its effect on yield of cacao—at Tafo,

2. Test of mild strain-induced immunity—at Tafo,

3. Demonstration of rate of spread of the Amafie virus and its effect on yield of cacao—at Wiawso,

4. Demonstration of rate of spread of the Busumuoso virus and its effect on yield of cacao—at Wiawso,

5. Comparison of six viruses of the Wiawso district for their effect on the yield of cacao—at Wiawso.

Experiments 1 and 3 to 5 are nearing completion and will probably be closed down in the coming year. Experiment 2, laid down in 1947, has not yet run for a critical period and the account given below refers only to a subsidiary function of the experiment—a yield comparison between healthy trees and those infected with a mild strain of virus 1A.

1. *Rate of spread and effect on yield of virus* 1*A*.

Unrestricted natural spread of virus 1A has been recorded for $4\frac{1}{2}$ years in a demonstration plot of $8\frac{1}{4}$ acres. When observations were commenced in August, 1945, 31 per cent. of the 4,636 trees were diseased ; by March, 1950, 90 per cent. were diseased. Figures indicating the rate of destruction during the first four years are given in Table 1.

TABLE 1.

INFECTED AND MORIBUND OR DEAD TREES IN $8\frac{1}{4}$ ACRES AT FIVE ANNUAL STAGES.

	Original total of mature trees.	August, 1945		August, 1946		August, 1947		August, 1948		August, 1949	
		Infected.	M. or D.*	Infected.	M. or D.*	Infected.	M. or D.*	Infected.	M. or D.*	Infected.	M. or D.*
Number	4,636	1,450	361	2,134	671	2,967	1,457	3,717	2,192	4,106	2,911
Percentage	—	31	8	46	14	64	31	80	47	89	63

*Moribund or dead ; the figure for infected trees includes that for moribund or dead.

The apparent reduction in rate of spread during 1948 and 1949 is due, of course, to the fact that the proportion of healthy to diseased trees within the plot boundaries has constantly decreased. The annual rate of infection of healthy trees increased from year to year until 1948–49 when there was a slight observed decrease. The actual rates are given in Table 2.

TABLE 2.

ANNUAL RATE OF INFECTION OF HEALTHY TREES BY VIRUS 1A ON THE RATE OF DESTRUCTION PLOT, TAFO.

1945–46	...	...	21 per cent.
1946–47	...	...	33 ,,
1947–48	...	...	45 ,,
1948–49	...	...	42 ,,

The total yield from the plot has fallen each year. The figures are given in Table 3.

TABLE 3.

ANNUAL TOTAL YIELD (NUMBER OF PODS) FROM THE RATE OF DESTRUCTION PLOT, TAFO.

Harvest Season.	Total Pods.
1945–46	41,771
1946–47	33,716
1947–48	24,569
1948–49	20,048
1949–50	10,115

Since 1947, the common local practice of replanting with beans at stake as the mature cacao becomes devastated has been carried out in this plot. About 18,000 seedlings were planted during 1947 and 1948, of which 94 (0·005 per cent.) had shown virus symptoms by March, 1950.

2. *The field protection test.*

The main object of this test is to determine whether mild strain-infection of trees results in an effective immunity to subsequent infection with a virulent strain of the same complex, as normally happens with young cacao plants. The experimental block comprises nearly three acres of peasant-planted Amelonado cacao containing 1,738 trees ; it is laid out as a rectangle measuring 400 × 320 ft. within which are 5 × 4 squares of 80 ft. sides. The treatment plots are 60 ft. sided squares, each set within one of the larger squares, using the same diagonals. The plots were taken in adjacent pairs and the two treatments, infection with a mild strain of virus 1A and control, assigned at random. Mild strain infection of the trees was carried out in the appropriate plots in July, 1947, using the patch grafting technique. The trees in all the perimeters were graft-inoculated with the virulent strain in March, 1948. The main observations have been concerned with the natural spread of the virulent strain from the perimeters into the plots and a short account of the results to date is given elsewhere in this report (p. 24). A secondary object of the experiment has been to glean some information on the effect of mild strain infection on yield.

With this in view, yield comparisons were recently made between two sets of eight sub-plots containing respectively healthy and mild strain-infected trees. Each sub-plot consisted of nine trees, all at least one tree removed from the nearest case of virulent strain infection ; otherwise the trees were selected at random. The mean yields of the sub-plots for the past three seasons are given in Table 4.

TABLE 4.

Harvest Season.	Mean yields of 8 sub-plots each of 9 trees.	
	Apparently healthy (Control).	Mild Strain-Infected.
1947–48	126·1	124·4
1948–49	164·9	166·8
1949–50	172·4	152·9

The annual yield increase with the apparently healthy trees doubtless indicates that the latter are yet to reach the stage of full production. The recent drop in the yield of the mild strain-infected trees appeared, from a simple analysis of variance, to be insignificant. The coefficient of variation was, however, of the high order of 40 per cent. and fine treatment differences were accordingly unassessable.

3 to 5. *The Wiawso experiments.*

These are nearing completion and a full account of the results is postponed until after the final readings are made.

Virus-Host Relationships.

In the past year some simple experiments have been carried out to test the effect of various abnormal cultural procedures on the build-up, availability and degree of virulence of virus 1A in infected material. In these experiments special attention has been directed to the effect on the host-virus combination of darkness, high temperature, various chemicals and abnormal nutrition. The results throw some light, albeit faint, on the type of relationship that exists between virus and host plant and are of preliminary value in connection with the problem of therapy.

Material. West African Amelonado seedling cacao and one fairly pure virulent strain of virus 1A have been used throughout. Plants were infected as beans by application of infective *Pseudococcus njalensis*, Laing, at a rate of 30 crawlers per bean. The appropriate treatment was usually commenced soon after infection. In some experiments where a small, simple and easily manipulable plant body was essential or highly convenient to the work, an infected cacao cotyledon with the embryonic axis removed was used as the host unit. Such "plants" have been kept viable for up to four months but this period could with care be extended. Mutilated cotyledons are incapable of showing virus symptoms and determination of infection has to be performed by the use of vectors.

(a) *Experiments to determine any effect of darkness on the availability and virulence of severe virus* 1A.

From previous work in which virus from infected tree roots was compared with that from the stem and canopy it was suggested that root-inhabiting virus tended to be milder than that from the above-

ground parts. Further results from similar work failed to support this suggestion. It was decided, however, that more stringent tests for qualitative virus differences between light-treated and dark-treated infected tissues should be carried out. The contention was that, since mild strains of virus 1A have little apparent effect on the chlorophyll system of infected plants while severe virus 1A is productive of a striking chlorosis, the milder components of the complex might well become dominant when infected tissue is maintained under conditions of complete darkness with consequent inhibition of the chlorophyll system.

Ten cotyledons from the same pod were treated by the removal of the embryonic axis and infected; on the following day each was planted, half-exposed, in steam-sterilized soil in a 100 cc. glass beaker. Alternate cotyledons were stored in a dark cupboard. The dark treatment was not absolute, since watering for instance had to be carried out in a dim light, but the intensity of darkness was sufficient to cause complete etiolation in germinating cacao seedlings.

After three months, by which time the exposed cotyledons were a dull olive green and the others without a trace of green pigment, three cotyledons from each treatment were infested with virus-free *P. njalensis* of uniform origin. Eighteen hours later, the mealybugs were transferred to cacao bean test plants at a rate of one per bean. The aggregate results are given in Table 5.

TABLE 5.

AGGREGATE TRANSMISSIONS OF VIRUS 1A FROM TWO GROUPS OF THREE INFECTED CACAO COTYLEDONS SUBJECTED TO LIGHT OR DARK TREATMENT FOR THREE MONTHS.

Treatment.	Vector Instar.	Aggregate Tests.	Transmissions.
Dark	Adult	325	42
Dark	Crawler ...	151	5
Light	Adult	247	58
Light	Crawler ...	142	5

After four months, only one of the two remaining dark-treated cotyledons was still alive and the two light-treated cotyledons had been reduced to a papery consistency as a result of autolysis. Transmission tests were carried out and the rates obtained were 1/69 from the dark-treated cotyledon and 0/172 from the two light-treated ones. It is thought that the low rate of transmission at this stage resulted from senescence of the host tissues.

The seedlings infected from the cotyledons were retained for four months so that any treatment-induced strain differences might be discerned. No such segregation of strains had in fact occurred and it was concluded that virulent virus 1A is capable of retaining its virulence under conditions of almost permanent darkness and that the same conditions are unlikely to be effective in causing a mild element of the virus complex to rise to dominance.

It was decided to investigate further the observed slightly greater availability of virus 1A from light-treated cotyledons. This work is still proceeding. In one experiment, 100 cotyledons without embryonic axes were infected and alternate cotyledons assigned to the dark treatment. Procedure was as in the earlier experiment except that the cotyledons were laid flat, just pressed into the surface of the planting medium, in this case sand, and all receiving the same treatment were set together in a tray. Cotyledons were tested for virus transmissibility at 5, 7, 9, 11, 12, 15, 17, 19 and 21 days after infection. For each test five cotyledons were chosen at random from each treatment and on the day prior to testing were infested with virus-free *P. njalensis*. The rate of vector transference to cacao bean test plants was 10 adults or 30 crawlers per bean. The augmented transference rate was adopted since testing was being carried out in the early stages of infection when virus concentration was likely to be low. The aggregate results from each batch of five cotyledons are given in Table 6.

TABLE 6.

AGGREGATE TRANSMISSIONS OF VIRUS 1A FROM GROUPS OF FIVE INFECTED COTYLEDONS SUBJECTED TO LIGHT OR DARK TREATMENT FOR DIFFERENT PERIODS OF TIME.

Days after infection.	Treatment.	Tests using adults.			Tests using crawlers.		
		No.	Transmissions.	Percentage.	No.	Transmissions.	Percentage.
5	Light	26	0	0	10	0	0
	Dark	22	0	0	7	0	0
7	Light	20	6	30·0	22	3	13·6
	Dark	13	3	23·1	10	3	30·6
9	Light	21	10	47·6	20	6	30·0
	Dark	13	5	38·5	6	1	16·7
11	Light	14	4	28·6	28	10	35·7
	Dark	13	5	38·5	11	3	27·3
12	Light	13	3	23·1	14	4	28·6
	Dark	10	3	30·0	8	0	0
15	Light	25	8	32·0	9	2	22·2
	Dark	30	11	36·7	13	2	15·4
17	Light	18	10	55·6	16	6	37·5
	Dark	15	6	40·0	9	5	55·6
19	Light	14	5	35·7	25	12	48·0
	Dark	15	7	46·7	15	9	60·0
21	Light	29	11	37·9	38	20	52·6
	Dark	25	22	88·0	31	24	77·4

It will be noticed that, under both treatments, virus was first transmissible from the cotyledons seven days after inoculation. From an inspection of the results obtained with crawlers it might appear that virus is more readily transmissible from light-treated host tissues during the early stages of infection, but the figures relating to adults give a reverse indication. For the purpose of statistical analysis, the experiment was treated as a 2 × 2 factorial test, the two factors being light and darkness and transmission by adults and crawlers ; the different test occasions (of which the first was omitted) were regarded as replications. No main effects or interactions were found to produce significant results.

The appropriate analysis of variance is given below :—

	Degree of freedom.	SS.	Variance.	SE.	Coefficient of Variance.
Instars	1	155·85	155·85	—	—
Illumination... ...	1	19·88	19·88	—	—
Instars × Illumination	1	50·70	50·70	—	—
Times	7	2646·44	378·06	—	—
Instars × Times ...	7	389·99	55·71	—	—
Illumination × Times	7	833·48	119·07	—	—
Instars × Illumination × Times (Error)	7	566·40	80·91	±8·995	24·48%

From these results, the main conclusion is that the essential activity of virulent virus 1A takes place at a level in the host cell deeper than that of the chloroplast system, though there is no indication that other phases of the plastid and related systems are not of critical importance. Certainly, symptom-production appears to be a secondary effect of the virus. This has in fact long been assumed because of the strong tendency even of virulent cacao viruses to enter upon symptomless phases of infection during which transmission is still possible.

(b) *The effect of high temperature on the availability and degree of virulence of virus* 1*A*.

Heat treatment, applied to infected tissue, is known to have a profound effect on some plant viruses, causing either inactivation or apparent attenuation. Appropriate experiments with infected cacao budwood have been carried out in the past, and it was postulated that no heat treatment which was not fatally injurious to host tissue had any noticeable effect on virulent cacao virus 1A. (Rep. Central Cocoa Res. Sta., Tafo, 1938–42, p. 57). In the current series of experiments, infected cacao beans and cotyledons are being used as experimental material and the heat treatment applied within a dark incubator. Beans are planted in sterilized soil or sand, each in a separate container.

It was found that germinating beans can be kept alive for at least two months at a continuous, almost constant temperature of 37·5°C. During the first day or two of treatment growth is accelerated, but thereafter, all further growth of the embryonic axis is inhibited. Treatment for periods of longer than three weeks may result in injury of the seedling to such an extent that growth of both plumule and radicle is still inhibited after cessation of the heat treatment. In a preliminary experiment virus was not transmissible from plants kept under treatment for 5 to 6 weeks though transmissions were obtained from the cotyledons of seedlings which had first been subjected to heat treatment for 14 days and then transferred to normal laboratory conditions for the remainder of the time.

In the next experiment, infected beans were kept at 37·5°C. for periods of 4 to 8 weeks. The object of this experiment was to discover whether the non-transmissibility of virus after upward of one month's heat treatment was due to irreversible inactivation of the virus or merely to temporary inhibition. It was also intended to show, in the event of the latter alternative being indicated, whether virus inhibition is complete or only partial during heat treatment.

Thirty newly-infected beans were planted, and all but seven, which were to serve as infection controls, were immediately placed in the treatment incubator set at 37·5°C. Up to six plants were removed from treatment after four, five, six and eight weeks and kept under normal room conditions. The cotyledons of all the plants except the controls (from which the cotyledons had dehisced) were removed and tested for transmissible virus at the eight-week period. Testing was carried out in the usual way, vector transference rates being 10 adults or 30 crawlers per cacao bean test plant. The transmission rates are given in Table 7 ; each rate is presented as a vulgar fraction, the denominator of which signifies the number of tests carried out and the numerator the number of transmissions obtained.

From these results it is evident that virus was able to build up after a period of up to six weeks heat treatment, during which it was presumably inhibited. On the other hand it appears that inhibition was complete while treatment was continued ; virus in treated infected cotyledons did not reach a transmissible level after an incubation period of eight weeks. It should be remarked in passing that inhibition was not accompanied by a greatly retarded host metabolism ; it was noticed that after eight weeks of heat treatment, the cotyledons had become appreciably thinner as a result of autolysis.

Transmissions were not obtained from Nos. 8 and 18 which were removed from the heat treatment three weeks before being tested and from No. 7 removed from treatment two weeks before being tested. These cotyledons were succulent at the time of testing and had reacted to light conditions by the development of chlorophyll. Normally, transmission of virus from infected cotyledons after an incubation period

TABLE 7.

TRANSMISSION RATES OF VIRUS 1A FROM COTYLEDONS OF CACAO SEEDLINGS INFECTED THROUGHOUT A LIFETIME OF EIGHT WEEKS DURING WHICH VARIOUSLY SUBJECTED TO A TEMPERATURE OF 37·5°C.

Period of heat treatment in weeks.	Instar	Seedlings as numbered with appropriate transmission rates.						Mean per-centage.
0–4		4*	9	14	19	24	29‡	
	Adults	—	0/6	2/8	2/6	2/7	4/8	22·8
	Crawlers	—	1/8	2/5	2/7	0/5	1/4	17·1
0–5		3‡	8	13†	18	23‡	28‡	
	Adults	5/6	0/4	0/4	0/4	3/4	3/5	24·2
	Crawlers	4/9	0/4	0/2	0/8	3/3	3/5	25·6
0–6		2	7	12†	—	22*	—	
	Adults	1/6	0/4	0/5	—	—	—	1·9
	Crawlers	1/9	0/6	0/2	—	—	—	1·3
0–8		1	6*	11	16	21	17	
	Adults	0/4	—	0/9	0/5	0/7	0/4	0
	Crawlers	0/5	—	0/4	0/5	0/4	0/11	0

* Dead.
† Cotyledon reduced to papery consistency.
‡ These Cotyledons were taken from plants which succeeded in growing ; the latter all showed virus symptoms either before or after the time of the test.

of 2 to 3 weeks presents no difficulty, and it is suspected that the failure in these instances was treatment induced. The cotyledons were kept for further testing and, four weeks later, Nos. 7 and 18 together with Nos. 1, 11, 16, 17 and 21 and the remainder of the surviving cotyledons, Nos. 9, 14, 19, 24, 29, 3, 28 and 2, were retested. Again no transmissions were obtained from Nos. 7 and 18 or from those which had undergone heat treatment for eight weeks. It is possible that these failures were due primarily to senescence of the cotyledons, as Nos. 9, 19, 3 and 2, which previously had been proved infected, also failed to give transmissions on this occasion. The question whether virus was actually inactivated in the cases cited remains an open one, and the issue is being given further attention.

Experiments are being conducted to test the effect on virus 1A of temperatures higher than 37·5°C. acting for short periods. At 42°C. the plumule of germinating cacao beans is killed by an exposure much exceeding 24 hours. Beans exposed for periods of up to 24 hours on subsequent development produced symptoms similar in appearance and time of development to those of the untreated controls,

In all the work on the effect of high temperatures on virus 1A, no instance of virus attenuation was encountered.

(c) *Experiments on the effect of certain chemicals on virus 1A.*

Attempts have been made to denature virus 1A in living plants by the use of certain chemicals found by Dr. E. M. Stoddard to be of therapeutic value against the virus of X disease of peach in the United States. (Bull. 506—Connecticut Agriculture Experiment Station, 1947.) The chemicals used were hydroquinone, quinhydrone, 8-hydroxy-quinoline, p-nitrophenol and benzoic acid ; aqueous solutions were applied to cacao beans which had, on the day previously, been infested with 30 infective crawlers of *P. njalensis*. In the first test the infected beans were immersed in a concentrated aqueous solution of quinhydrone (one of Dr. Stoddard's most effective chemicals), for two or four hours, before being planted. As a result of treatment, the plumules were killed but root growth was apparently unaffected. Virus denaturation did not occur ; transmissions were later obtained as easily from cotyledons of the treated plants as from those of the controls.

In a second test, aqueous solutions of the following chemicals were used in the strengths mentioned : half-saturated 8-hydroxy-quinoline, ·25 per cent. benzoic acid, ·125 per cent. p-nitrophenol, ·25 per cent. hydroquinone. Ten beans were subjected to each treatment and nine to the control. The beans were immersed for three hours, then planted. A certain amount of permanent plumule damage was again encountered but a sufficient number of plants survived each treatment for a conclusion to be reached. The results are given in Table 8.

TABLE 8.

EFFECT OF VARIOUS CHEMICALS ON VIRUS 1A IN NEWLY INFECTED BEANS.

Chemical in aqueous solution	Transmissions obtained in surviving test plants (out of ten).
½ sat. 8-hydroxy-quinoline	9–10
·25% benzoic acid ...	4– 4
·0125% p-nitrophenol ...	8– 8
·25% hydroquinone ...	5– 5
Control (distilled water)	7– 7 (out of nine)

None of the chemicals proved effective in the experimental conditions employed. The time of application of the chemicals, just after infection of the material, was thought to be optimum for virus denaturation. It would seem that virus 1A forms a much more stable and intimate association with cacao tissue than does X disease virus with peach.

(d) *The effect of abnormal nutrition on virus* 1*A-infected plants.*

An experiment is proceeding in which plants infected from the bean stage are being subjected to different levels of nitrogen, phosphorus and potassium nutrition. Treatment " units " of N, P and K are applied in nutrient solution to plants growing in sand ; N is applied at a rate as contained in 16 milliequivalents of a nitrate and two of an ammonium salt, P in two milliequivalents of a phosphate and K in ten milliequivalents of a potassium salt per litre. The following treatment combinations are being tested : N, P, K, NP, NK, NPK, NPK (without sulphur), N_2PK, NP_2K, NPK_2 and O (tap water). Application of solutions is at a rate of 500 c.c. per plant four times weekly. Four pots of seedlings were assigned to each treatment combination, each pot containing first four and later, two seedlings. The pots are moved daily to counteract differences in light intensity at different parts of the greenhouse.

Conspicuous effects have been produced on the plants by some of the treatments, but no treatment has caused any but minor effects on virus symptom expression. A fuller consideration of these minor differences will be made later.

Studies on the Virus 1*A Complex.*

It has been shown that virus 1A, the causal agent of one of the most virulent forms of swollen shoot disease, exists as a complex of strains. Mild elements are capable of immunising test plants against virulent strains ; this reaction forms, indeed, the sole criterion of close relationship between cacao viruses. Two or more strains can cause simultaneous infections in the same plant, a fact which might seem out of keeping with the property of immunisation just mentioned. It has recently been demonstrated, however, that the two events, immunisation and simultaneous infection, are not incongruous and that there are times when the immunity conferred by a mild strain can be broken down ; furthermore, from a comparison of the results of several experiments, it seems that certain mild strains of virus 1A are more efficient immunising agents, at least against some virulent strains, than are others. In passing it should be mentioned that the existence of these recently discovered qualities increases the strength of the argument *against* the artificial immunisation method of cacao virus control.

The results which have already accrued from these studies are presented as follows.

(a) *Experimental breaking-down of mild strain-induced immunity.*

The first experimental breaking-down of induced-immunity was an accidental achievement. A test was set up to ascertain whether five randomly chosen virulent viruses from the Eastern Province of the Gold Coast were immunologically related. All had some distinguishing feature in their symptoms which were nevertheless similar. It had been assumed hitherto that the viruses were related, because of similarity in symptoms and virulence and their natural geographical proximity.

Thirty saplings already infected for 17 months with an almost symptomless Eastern Province strain were used as test plants. They were divided into six groups of five, the plants of each of five of the groups being reinoculated by patch grafting with one of the five virulent viruses; the sixth group contained the controls which were not reinoculated. Five healthy saplings were inoculated from each of the five virulent virus source plants to act as infection controls. Immediately after virulent virus inoculation the test plants and controls were coppiced at a height of two feet to hasten the experiment. [It was believed at the time that coppicing was a permissible treatment. Some time previously, mild strain-infected saplings which had been reinoculated with severe virus two to three years before were similarly coppiced and produced new growth which was either symptomless or bore occasional symptoms of the mild strain only.]

After the first two flushes of new growth from the coppiced plants had matured it was noticed that symptoms of the virulent virus had been produced on one or more of the test plants of each group. It was then thought that immunological relationship of the virulent viruses to the mild strain had been disproved. In the later flushes, however, with the plants belonging to four of the five groups, virulent virus symptoms either did not appear or did so only on occasional flushes; with the infection controls, on the other hand, the symptoms of the virulent virus were present on the leaves of every flush and growth was greatly retarded. The plants of the fifth group did not recover and it was concluded that immunological non-relationship of the viruses concerned had been demonstrated.

A year later, it seemed that the introduced virus had been completely or almost completely suppressed in groups one to four, and the plants were again stumped. Observations on the second new growth are still being made, but at three months after recoppicing, virulent virus symptoms were seen on only one of the reinoculated plants of groups one to four. Thus, arguing from the evidence produced by symptoms, it seems that a virulent strain of virus 1A, after being inoculated into a mild strain-infected plant which is immediately coppiced, can multiply even to the level of symptom-expression but is later almost completely suppressed. The history of each mild strain-infected test plant is given in Table 9.

TABLE 9.

THE SYMPTOM HISTORY OF PLANTS INFECTED WITH A MILD STRAIN OF VIRUS 1A AFTER SUPERINFECTION WITH A SEVERE STRAIN OF THE SAME VIRUS.

Group.	Plant.	Name of Reinoculated severe virus.	Growth after first coppicing			Growth after second coppicing
			Final vigour.	Occurrence of severe virus symptoms in early flushes.	Occurrence of sporadic severe virus symptoms in later flushes.	Virus symptoms in early flushes.
1	1	VI	Good	+	+	virulent strain.
	2	,,	died early in experiment.			
	3	,,	Good	—	—	absent.
	4	,,	,,	—	—	mild strain.
	5	,,	,,	—	—	absent.
2	1	TY	,,	+	—	mild strain.
	2	,,	,,	+	—	absent.
	3	,,	died early in experiment.			
	4	,,	Good	+	—	absent.
	5	,,	,,	—	—	,,
3	1	PC	,,	+	+	mild strain.
	2	,,	,,	+	+	,, ,,
	3	,,	,,	—	—	absent.
	4	,,	,,	—	—	,,
	5	,,	,,	+	—	mild strain.
4	1	197C	died early in experiment.			
	2	,,	Good	—	—	absent.
	3	,,	,,	+	+	mild strain.
	4	,,	,,	+	+	,, ,,
	5	,,	Poor	+	+	? (leaves uniformly chlorotic).
5	1	150	,,	+	+	virulent virus.
	2	,,	,,	+	+	,, ,,
	3	,,	Good	+	—	,, ,,
	4	,,	Poor	+	+	,, ,,
	5	,,	,,	+	+	,, ,,
6	1	Control	Good			mild strain.
	2	,,	,,			,, ,,
	3	,,	,,			,, ,,
	4	,,	,,			absent.
	5	,,	,,			mild strain.

As these results are of some theoretical interest, care is being taken to repeat the work. The second experiment is essentially similar to the first though in an expanded form. It is still continuing, but sufficient results have accrued to merit an account.

The mild strain used for pre-infection in this experiment is the one responsible for resistance in the clone SS167 ; the virulent viruses are TY, PC, 197C and 150 as used in the first experiment. The test plants had been infected with the SS167 strain for 20 months at the time of reinoculation. They were divided into five groups of ten plants ; in each of four of the groups, the plants were reinoculated, by patch grafting, with one of the virulent viruses while those of the fifth group were retained as controls. Each group of test plants is controlled by an exactly similar group of saplings infected with virulent virus 1A which, throughout the experiment, has been treated similarly to the test plants. Coppicing was carried out on three occasions to test whether, as seemed likely from the earlier observations, virulent strain build-up in pre-infected plants is inhibited or suppressed when reinoculation precedes coppicing by some time. Three plants of each group were coppiced at the time of the second inoculation, a further three, three weeks later (by which time graft union would be complete) and the remaining four after eight months.

The effect of delaying coppicing treatment for eight months is not yet known, but from the test plants treated on the first two occasions ample evidence has been obtained of the build-up of virulent virus in mild strain-infected material. The effect of virulent virus infection has been much more severe and prolonged in this experiment than in the previous one and as yet there is not much evidence to indicate an eventual suppression of the virulent strains. From symptom observations taken over a period of ten months, virulent virus seems to have been suppressed in the following instances :—

1. In 3 out of 6 test plants virus TY has been suppressed.
2. „ 0 „ „ 6 „ „ „ PC „ „ „
3. „ 0 „ „ 6 „ „ „ 197C „ „ „
4. „ 0 „ „ 6 „ „ „ 150 „ „ „

From comparison of these fractions with the comparable ones from the first experiment, it would appear that the mild strain from the clone SS167 is not as effective an immuniser as the one previously employed.

As it was felt that corroboration of the symptomological evidence of severe strain invasion was desirable, transmission tests were carried out at the second flush stage of the new growth. The results, which are given in Table 10 show clearly that an at least temporary breakdown of mild strain-induced immunity can occur.

TABLE 10.

TRANSMISSION RATES OF DIFFERENT STRAINS OF VIRUS 1A OBTAINED FROM MILD STRAIN-INFECTED TEST PLANTS SUPERINFECTED WITH VIRULENT STRAINS, TOGETHER WITH APPROPRIATE FIGURES RELATING TO THE VIRULENT STRAIN-INFECTED CONTROLS.

(Rate of vector transference, one adult or crawler per cacao bean test plant.)

Nature of plant.	Virulent virus used in reinfection.	Number of transmission tests.	Virus strain transmissions.		
			Mild.	Virulent.	Undetermined†
M* ...	150	90	1	0	1
M ...	150	100	1	3	4
Control ...	150	18	0	3	1
Control ...	150	32	0	0	0
M ...	PC	100	1	8	3
Control ...	PC	112	0	18	3
M ...	TY	48	1	2	0
Control ...	TY	32	0	4	1
M ...	—(control)	10	0	0	0
M ...	—(control)	62	4	0	0

* Mild strain-infected test plant.
† The result of infection with either both virulent and mild viruses or a strain of intermediate virulence segregated from the complex.

Work on immunity break-down is continuing but it is already evident that mild strain-induced immunity to virulent strains is not the absolute condition it has hitherto been assumed to be. In past experiments, using continuously growing saplings, immunity apparently broke down, but so rarely that other explanations of the phenomenon were always conceivable. It is obvious that the existing concept of induced immunity will have to be revised, but at the present tentative stage of these investigations it would be unwise to attempt to enunciate a more appropriate hypothesis.

(b) *The field test of mild strain-induced immunity.*

In view of the recent discoveries relating to mild strain-induced immunity, critical results from the field protection experiment are awaited with enhanced interest. It is yet impossible to suggest what the outcome of this experiment may be but the figures at present available indicate that pre-infection of trees with a mild strain has at least an inhibiting effect on the rate of spread of a severer strain of the same complex. The layout of the experiment is described elsewhere in this report (p. 12). It will be recalled that the control and mild strain-treated plots, the trees of which were inoculated with the mild strain of virus 1A in July, 1947, are all surrounded by trees which were inoculated with a severe strain of virus 1A in March, 1948. The experiment was perforce

laid down in an area surrounded by swollen shoot outbreaks and virulent strain became evident in a few mild strain-treated trees through prior infection. In order to discount this, all virulent infections which appeared in the control and treated plots before 1st January, 1949, have been disregarded. Since then, no mild strain-infected tree has shown severe symptoms but some bear twig swellings, a symptom previously unrecorded from the mild strain-infected trees in this experiment. For the purpose of a recent analysis, all trees bearing swellings on the treated plots were regarded as harbouring the virulent strain. In the ten treated plots, the mean percentage of trees considered on that basis to be severe strain-infected was only 6·1 per cent. as against a mean severe strain infection rate of 31·2 per cent. for the control plots. This difference was found to be significant at the 5 per cent. probability level.

Resistance to Virus 1*A*.

In the past year, tests for comparative resistance to severe virus 1A have been confined almost exclusively to cacao of Upper Amazon Forastero origin. This material is available only as beans or seedlings of unknown male parentage, the maternal parents being second generation descendants of trees selected by the late Dr. Pound in the region of the headwaters of the Amazon. The material then, is not genetically pure but at first this is probably desirable for work which aims at the discovery of effective disease resistance or immunity in a plant population.

It will be recalled that in earlier tests, progenies resulting from crossing of the Nanay and Parinari types showed significantly greater resistance to infection by vectors feeding on the bean cotyledon than did West African Amelonado. Seedlings remaining uninfected after these tests were retested when about six months old by infestation with infective *P. njalensis* at a rate of 30 insects per plant. The resultant mean rate of infection in the Nanay × Parinari cacao was 3·64 $\pm$ 0·61 out of ten and in the Amelonado 5·43 $\pm$ 0·81 out of ten ; the difference between the means was found to be not significant at the 5 per cent. probability level.

During the 1949–50 harvest season, an endeavour was made to subject the beans from at least six pods of each important Upper Amazon type to comparative resistance tests. The procedure was similar, except in detail, to that of the previous season. Beans (with one cotyledon removed to facilitate the settling of the vectors) from each selected pod were tested against similarly treated beans from an unselected pod of West African Amelonado ; selected and control beans were infested alternately, the rate per bean being five infective crawlers of *P. njalensis* from the same feeding source. The same moderately pure strain of severe virus 1A was used in all the comparisons. After infestation, the beans were allowed to germinate to the stage of third or fourth flush seedlings when symptom observations were made and most of the seedlings were discarded. A sample of not more than six symptom-bearing seedlings of both selected and control types was usually retained from each test for further symptom observation and experiment. During the season, nearly 9,000 plants were involved in this work.

Cacao of Upper Amazon origin was again found to be comparatively more resistant to infection and also more tolerant of infection than was West African Amelonado.

The greater resistance to infection was revealed by the fact that fewer beans of the Upper Amazon types than of the Amelonado became infected. Resistance was significantly greater at the 5 per cent. point in beans from trees of the following origin : Nanay × Nanay, Nanay × Parinari, Parinari × Nanay, Nanay × Iquitos and Iquitos × Nanay. No significant resistance was discovered in beans of the following origin : Parinari × Parinari, Scavina × Scavina and Iquitos × Iquitos. It would seem from these results that effective resistance may be resident in the Nanay population and it is of interest to note that of the 14 sets of comparative resistance tests under consideration, the two sets involving Nanay × Nanay progeny were respectively second and third in the degree of significance of the difference between treatments. First place was actually taken by a set of Nanay × Iquitos progeny ; only with regard to these three sets did the level of significance reach the 1 per cent. probability point.

The comparatively greater tolerance of infected Upper Amazon seedlings is very noticeable and is reflected in three ways : (1) a longer incubation period, (2) a greatly reduced and sometimes evanescent symptom expression and (3) greater vigour of infected plants. From one small experiment recently carried out it was indicated that the state of tolerance does not presume either reduced availability of the virus to vectors or any qualitative change in the virus.

It is stressed that the degree of resistance so far rendered evident within the Upper Amazon population is of theoretical interest only and is of no practical significance. In the coming season, a series of much more stringent tests for high resistance or immunity will be carried out on material from the Nanay and other promising types at our disposal.

Alternative Host Plants of Cacao Viruses.

Alternative host work has continued along three main lines, (1) the host range of the cacao viruses, (2) virus-host relationships with reference to alternative host species and (3) the search for alternative hosts in the field.

The Host Range of the Cacao Viruses.

In previous years, the host range, particularly of cacao virus 1A, was given extensive study ; all the common forest species of Sterculiaceae and Bombacaceae and many more distantly related or unrelated species common in cacao farms were tested. The main results of those test series were as follows : *Cola cordifolia* R. Br., *Erythropsis Barteri* K. Schum. (Sterculiaceae), *Adansonia digitata* Linn., *Bombax buonopozense* P. Beauv. and *Ceiba pentandra* Gaertn. (Bombacaceae) could be infected with virus 1A, and most also gave positive results with some other viruses ; *Cola chlamydantha* K. Schum., *Sterculia rhinopetala* K. Schum., and

S. tragacantha Lindl. (Sterculiaceae) could be infected with some viruses but apparently not with virus 1A ; *Cola nitida* A. Chev., *C. togoensis* Engl. and Krause and *Triplochiton scleroxylon* K. Schum., all common and important species of Sterculiaceae, could not be infected with any of the cacao viruses tried, as was also the result with species of Malvaceae, Tiliaceae and other families more distantly related to Sterculiaceae.

At present, a more intensive study of some species and viruses is being made. It is regarded as of prime importance to know whether the negative results of the earlier tests are reliable since the host range of a virus might come to be used as a character of special taxonomic or physiological significance. Attention was primarily given to the problem of whether infection of *C. chlamydantha*, *S. rhinopetala*, *S. tragacantha* and *T. scleroxylon* with virus 1A is possible. Intensive methods are also being used in extending knowledge of the host range of a few viruses and in carrying out initial tests with further species both within and without the families Sterculiaceae and Bombacaceae. The essence of the intensive method is to use, if possible, recently germinated host seedlings which are subjected to heavy bombardments of infective vectors and from which the first back-tests to cacao are carried out within two months of bombardment, irrespective of whether symptoms are developed. The number of host seedlings per test is five and each is given, usually within the space of a week or so, three bombardments of 100 nymphs or crawlers of *P. njalensis* freshly removed from a young seedling cacao source plant ; cacao bean controls are infested alternately with the host seedlings at a rate of 30 insects per bean. In passing, it should be remarked that almost every cacao control in the current series of tests has shown virus symptoms in the first flush, thus indicating the highly infective nature of the insects used. The palatability of the host seedlings to *P. njalensis* is not generally as high as is cacao cotyledon but, in most cases, seemingly adequate numbers of insects are still present and apparently feeding on host tissues 18 to 24 hours after application. Back-tests for infection are made at roughly two, three and six month intervals after the second infection bombardment. The six months test is intended to show whether virus availability, if already proved, is maintained. The vector *P. njalensis* is invariably employed, the rate of transference in back-tests being 10 adults or 30 crawlers per cacao bean test plant.

Few positive results from the intensive tests are yet available but it has been proved, contrary to earlier indications, that both *S. rhinopetala* and *S. tragacantha* are capable of becoming infected with virus 1A. Back transmissions were obtained from 1/5 and 2/5 of the respective sets of host seedlings ; the aggregate transmission rates from back tests carried out two to three months from the second infection bombardment were 4/28 for the specimen of *S. rhinopetala* and 1/55 and 8/44 for the two specimens of *S. tragacantha*. These transmission rates are much lower than would be expected from cacao plants of similar age, a fact which is strongly suggestive of relatively greater resistance to virus build-up in the *Sterculia* spp. since there is no comparable difference in the palatability of the respective host tissues to the vectors.

Virus-Host Relationships.

It has been observed with all known alternative host species, except *C. chlamydantha*, that transmission of virus from infected specimens tends to be irregular and difficult. The vector *P. njalensis* has been largely employed in alternative host investigations but similar results were achieved with other vectors, and it seems unlikely that the difficulties are due merely to inefficiency of the vector species employed. There is, on the other hand, every indication that the relationship between alternative host tissues and virus is much more tenuous than is the case with cacao. The suggestion has been made that the virus might even die out after preliminary infection in certain species. An experiment was recently carried out to test this hypothesis for *C. pentandra*, using some young symptomless plants infected 1½ to 3 years before. The plants were coppiced, a treatment conducive to virus build-up in cacao, and the resultant shoots were detached for testing within three months of coppicing. Virus-free *P. njalensis* were applied to the detached leaves and green stems and, after two days, feeding insects were transferred to cacao bean test plants at rates of 10 adults or 30 crawlers per bean. The plants were recoppiced at each test and the subsequent growth tested, usually within two months. In this way up to three successive crops of shoots were tested from each plant. The results are given in Table 11.

TABLE 11.

TRANSMISSION RATES OF VIRUS FROM SUCCESSIVE SHOOTS DEVELOPED AFTER REPEATED COPPICING OF INFECTED *C. PENTANDRA* SAPLINGS

Plant	Virus	Duration of infection at first coppicing	Transmission rates from the stems detached on coppicing	Transmission rates from successive young shoots.		
				1	2	3
CP3	1A	3 years	5/58 (8·6%)	32/104 (30·8%)	76/139 (54·7%)	49/79 (62·0%)
CP12	1A	3 years	0/18	4/53 (7·5%)	—	—
WS167	1J	1½ years	0/48	15/54 (27·8%)*	0/57	0/76
WS56	Suhuma (Westn. Prov.)	1½ years	0/77	0/65	0/60	0/25
WS83	Aiyiboso (Westn. Prov.)	1½ years	0/78	0/74	0/36	0/51

*This result should be taken with reserve. The symptoms in cacao are unlike those of virus 1J and the transmissions here recorded might have been due to inadvertent contamination.

It will be seen that virus was recovered from the treated specimens infected with virus 1A, though prior to treatment, transmissions either were not obtained or obtained at a low rate. Transmissions were not obtained from the similarly treated specimens infected with other viruses. Further attention is being given to this anomaly.

Most of the evidence hitherto cited for the greatly reduced transmissibility of virus from alternative hosts has been of a rather incidental nature. An experiment is now being conducted in which the history of virus infection in seedlings of *C. pentandra* and *C. cordifolia* is being given direct study.

Five small seedlings of each species were thrice bombarded with infective adults and crawlers of *P. njalensis* at a rate of 50 insects per plant per bombardment. All the plants were infested with virus-free *P. njalensis* from the same source at subsequent successive periods of 7 to 8 weeks, the first period being measured from the time of the second infection bombardment. Mealybugs, after having fed on the host tissues, were transferred to cacao bean test plants at the rate of 10 adults or 30 crawlers per bean. Immediately after the fourth test, the plants were coppiced and the detached stems and leaves again tested. The plants are now being coppiced regularly and transmission tests carried out on the detached young shoots. Results to date are presented in Table 12.

TABLE 12.

TRANSMISSION RATES OF VIRUS 1A FROM SEEDLINGS OF *C. PENTANDRA* AND *C. CORDIFOLIA* AT SUCCESSIVE STAGES OF INFECTION.

Species.	Plant.	Symptoms.	Testing occasion (see text).					
			1	2	3	4	5*	6†
C. pentandra	1	+	5/10	0/9	0/1	0/10	0/35	0/95
	2	—	0/5	0/7	0/16	0/7	0/36	0/49
	3	+	2/8	0/6	0/10	0/2	0/47	0/72
	4	+	6/6	0/3	0/3	0/12	0/39	0/51
	5	+	0/4	0/8	0/5	0/5	0/47	0/38
C. cordifolia	1	—	0/8	0/10	0/7	0/10	0/62	0/84
	2	—	0/7	0/22	0/10	0/9	0/80	0/58
	3	—	0/9	0/16	0/1	0/20	0/61	0/51
	4	—	0/6	0/10	0/5	0/12	0/63	0/52
	5	+	0/8	0/6	0/14	—	0/71	—

* Test made from detached stem material.
† The first test on young shoots from the coppiced stumps.

It is obvious from this experiment that virus can build up to a transmissible level in *C. pentandra* shortly after infection. This phase is doubtless homologous with the acute phase of symptom-expression in cacao. Subsequently virus becomes of greatly reduced availability (in this experiment non-available) to vectors and the circumstances attending any further build-up have not yet been established. With *C. cordifolia* there is as yet no direct proof that the plants in this experiment became infected, though symptoms, undoubtedly those of virus, were seen on one plant. The striking fickleness of virus transmissibility from alternative

hosts is well brought out in this experiment and the resultant main difficulty of field work indicated.

The Search for Alternative Hosts in the Field.

(a) *In the Tafo district of the Eastern Province.*

In the course of previous work, transmissions of virus 1A were obtained at a low rate from canopy twigs of two medium sized trees of *C. pentandra* growing contiguously on W.A.C.R.I. land. It was decided to utilize the stumps of these two trees in an attempt to find what might constitute a reasonable number of tests for the discovery of virus infection in field material. At first, living tissue on which mealybugs would feed was obtainable only from the stump and roots. Several large pieces were cut from the buttresses and roots of each tree and portions of each piece infested in the laboratory with virus-free *P. njalensis*. After a feeding period, usually of 48 hours, the insects were transferred to cacao-bean test plants at rates of 10 adults or 30 crawlers per bean. The results are summarized in Table 13.

TABLE 13.

TRANSMISSION TESTS FROM THE BUTTRESSES AND ROOTS OF TREES KNOWN TO BE INFECTED WITH VIRUS 1A.

Tree.	No. of buttress pieces tested.	No. of root pieces. tested.	No. cacao bean test plants used.	Trans-missions.
C. pentandra No. 15 ...	12	17	530	0
C. pentandra No. 21 ...	9	15	565	0

The young shoots which developed from the stumps were also used in transmission tests. A total of 349 tests was made from both trees, using sucker material, but no virus transmission was obtained.

Some idea of the difficulty confronting any investigation of alternative hosts in the field may be gathered from the negative results of this intensive study of two trees known to be infected. As many as 25,000 insects were used in the transmission tests, yet corroboration of infection was not obtained.

The natural suspicion that the original infections resulted merely from contamination has happily been allayed by the recent discovery that a third contiguous young specimen of *C. pentandra* is infected. In this case, a single transmission was obtained from 449 tests carried out on several occasions ; the tests were made on suckers taken from the stump.

Twenty other specimens of *C. pentandra* from the same neighbourhood have been similarly tested, involving a further 1,851 tests. No virus transmission was obtained from these trees.

The testing of young *C. pentandra* growing in what were two large attacks of swollen shoot is being carried out. So far no transmission has been obtained.

(b) *In the Wiawso district of the Western Province.*

Field work on *C. chlamydantha* has been continued as circumstances allowed. Virus infection of that species has now been demonstrated through an area of about 200 square miles centred on the town of Wiawso. Infected specimens were found in two separate zones of the Suhuma Forest Reserve, indicating widespread infection of this species in certain areas not yet under cacao cultivation.

Addendum.

In view of certain misconceptions which have arisen concerning the importance of alternative hosts to the West African cacao economy, the following speculations on the status of alternative hosts are advanced. The views expressed are solely those of the officer engaged on alternative host work and only as such, and not as an official view, do they merit attention.

1. " Cacao " viruses have been present in the forest for perhaps hundreds of years. During this time, the virulence of the viruses in relation to large hosts like *C. pentandra* and *C. cordifolia* has been greatly reduced, if indeed it was ever greater than it now is. Virus infection of *C. pentandra* etc., is now widespread throughout West Africa, though only a small proportion of the trees may actually be infected.

2. Spread of virus among the large alternative hosts is slow because of low virus availability to vectors and the discontinuity of the host canopies. The effects of mutation are thus pronounced and the general absence of close relationship among the many " cacao " viruses explicable.

3. Spread of infection from the large host species to cacao is rare and sporadic, thus accounting for the fact that, though outbreaks in cacao are now scattered over much of the West African cacao belt, as yet only a minority of the total cacao is infected.

4. Infection of *C. chlamydantha* occurred after the large hosts were infected ; the viruses are more virulent in relation to this species than to the larger tree hosts.

5. Virus infection in *C. chlamydantha* preceded cacao cultivation, and considerable virus variation has occurred in that host. Transmission of virus from *C. chlamydantha* to cacao is exceptionally easy and previous variation is rendered evident by the multiplicity of cacao viruses in the Wiawso district.

Except for *C. chlamydantha*, alternative hosts present a chronic and not an acute problem. It should be appreciated, however, that more and more apparently new viruses will probably appear in cacao from the host species of the forest.

The Mealybug Vectors of Cacao Viruses.

Work during the year has been restricted to two projects.

1. The extraction and analysis of the quantitative data from the mealybug populations experiment. This experiment was commenced in April, 1947, and was concluded in June, 1949.

2. The monthly examination of 2,920 Upper Amazon cacao seedlings planted at the cacao station of the Department of Agriculture at Oyoko. Besides accumulating data on mealybug infestation of these seedlings, preliminary observations have been made on the incidence of a beetle borer found damaging seedling cacao.

The Mealybug Populations Experiment.

The final analysis of the data from this experiment has been completed, and the work has been written up for publication in two parts, the first part dealing with the taxonomy and biology of the insect species closely associated with the field transmission of swollen shoot, the second dealing with the ecology of these species and their interactions on a quantitative basis. The more important results not already published are :—

(*a*) Mealybug density is closely correlated with the density of ants of the genus *Crematogaster* and the ants construct their carton tents in relation to the numbers of mealybugs to be protected. It is believed that the association between the ants and mealybugs is primarily of advantage to the ants. The ants are responsible for the maintenance of a " protected steady density " of *P. njalensis* in the face of predacity by natural enemies of that species.

(*b*) No direct correlation is apparent between mealybug density and incidence of swollen shoot, though populations in areas devastated by virus are generally lower than in areas in which virus is actively spreading.

(*c*) It has been established that rainfall has little, if any, effect, on *P. njalensis* density, though the other cacao feeding pseudococcids are significantly negatively correlated with monthly rainfall.

The Oyoko Observations.

The Amazon cacao plots have been examined eleven times to date. The mealybug infestation rate has varied from 2·2 per cent. in September/October to 11·4 per cent. in January/February. The seedlings were painted twice with D.D.T. in the course of the year as protection against capsid attack, but this operation had no apparent effect on mealybug infestation which, after the November painting, rose from 4·6 per cent. to 6·5 per cent. The experiment is to be terminated in May, when the results will be examined in detail.

Three monthly counts were made on the incidence of *Xyleborus morstatti* Hgd., (determined by Mr. D. J. Atkinson of the Commonwealth Institute of Entomology). In December this beetle was present on 1·9 per cent. of the seedlings, in January on 3·1 per cent., and in February on only 1·1 per cent. Although the pest is not sufficiently common to cause grave concern, it seems advisable to keep it under observation. The fungi *Botryodiplodia theobromae* and *Calonectria rigidiuscula* were isolated from lesions caused by the beetles.

The Coccid Collection.

The coccid collection has been increased during the year by 46 tubes of specimens. No new material has been discovered (with the possible exception of a species of *Aspidoproctus* which may turn out to be an undescribed species). Collections of named coccid material have been prepared and presented to the Department of Agriculture, Nigeria, and to Dr. Harold Morrison for the U.S. Department of Agriculture Bureau of Insect Identification, Washington, D.C.

III. CAPSID RESEARCH.

Capsid Physiology.

Preliminary investigation of the digestive physiology and anatomy of the capsid bugs has been completed and more detailed studies are continuing. So far as the anatomy and histology of the alimentary system are concerned, only a few details remain to be elucidated.

The alimentary canal consists of three principal regions, the fore, mid and hind-gut ; the mid-gut is further sub-divided into three distinct portions. There are thus five regions in the alimentary canal, and adjacent sections are separated from each other by a constriction or valve.

The fore-gut is short, ending just behind the brain and is supplied with muscles which enable it to act as a powerful sucking apparatus.

In the mid-gut, the most anterior region is capable of distension and contraction and its cells vary between a columnar and a flattened, " pavement " epithelium. There appears to be a periodic secretion of opaque granular material by these cells, but its function is still obscure. The middle-region cells are smaller, with lobes projecting into the gut lumen, and with a " brush-like border " as is usually found in the gut epithelium of insects. The posterior mid-gut cells are simple and bear on their surface the symbiotic organisms mentioned below.

In the anterior mid-gut, or " stomach ", the presence of commensal bacteria is suspected, and in the posterior mid-gut there are symbiotic yeast-like or protozoan organisms which consist of minute worm-like bodies attached at one end to the gut cells and with a bulbous swelling at the other end. Their true nature is still being investigated.

The digestive ferments of the salivary glands and of the different regions of the mid-gut have so far only been tested as regards a diastase. A strong diastase is present in the salivary gland and anterior mid-gut (though in the latter it may be only a product of ingested saliva) but not in the accessory salivary gland or posterior mid-gut.

Nematode Parasites of Capsids.

Several specimens of a nematode have been obtained from the body cavity of *S. singularis* and *D. theobroma* during dissections for other purposes.

Capsid Behaviour.

Temperature Gradient Experiment.

In order to observe the reactions of the insects to different temperatures, an apparatus was set up essentially similar to that described by V. B. Wigglesworth (Parasitology, Vol. 33 (1941), pp.73–4), whereby a temperature gradient could be established.

Males and females of *S. singularis* and *D. theobroma* were tested separately in the gradient, in groups of from two to eight individuals according to the numbers available, and their distribution with regard to temperature was observed fifteen minutes after introduction. The insects were then scattered evenly over the chamber and their distribution was again noted after a further fifteen-minute interval. The accumulated results are shown in the following Table :—

TABLE 14.

Temp. (° C.).	*S. singularis.*		*D. theobroma.*	
	Females.	Males.	Females.	Males.
17–19	31	0	48	5
20–22	24	2	26	5
23–25	23	12	39	10
26–28	21	7	34	4
29–31	24	4	20	8
32–34	28	13	26	11
35–37	21	5	35	2
38–40	9	2	27	1
41–43	9	2	8	2

Records above and below the temperature range shown are unreliable, since the insects are trapped in condensation water below 16° C. and above 43° C., they rapidly become moribund.

The frequency curves of distribution with regard to the temperature are bi-modal in all cases, with a lower mode at 17° to 19° for females and 23° to 25° for males. A second mode occurs at 32° to 34° except in the

case of females of *D. theobroma*, when the mode occurs at 35° to 37°. In the higher part of the range, the curves rapidly fall away, but females of *D. theobroma* appear to tolerate high temperatures better than do the other insects tested.

It was observed that insects collected in the dry season tended to congregate at a higher point along the temperature gradient than did those collected at other seasons. No significant correlation however could be established between original cage temperature and the final distribution on the gradient.

Initiation of Capsid Pockets.

Field experience indicates that one of the most important factors inducing capsid invasion is a break in the cacao canopy. This has been confirmed by a previous experiment (Annual Report 1946–7, p.35). A breach in the canopy brings two obvious new factors into play, namely an increase in light intensity and also an increase in chupon production. The experiment now discussed was designed to investigate the relative importance of these two factors.

Three blocks of cacao were chosen in the Square Mile, each block being as uniform as possible in density of overhead shade and in the continuity of the cacao canopy. Three plots, each 30 feet square were laid out in each block, the plots being treated as follows :—

(*a*) Control plot ... Untreated.
(*b*) Unshaded plot ... Cacao trees pollarded at 4 ft.
(*c*) Shaded plot ... As (*b*) but the plot covered with matting shade eight feet above the ground.

As the area covered by the cacao canopy was uniform in each block, the area, and not the number of trees, was chosen as the basis of evaluation of the population. The actual number of trees per plot is as follows :—

TABLE 15.

Blocks.	Treatments.		
	(*a*)	(*b*)	(*c*)
1 ...	23	28	25
2 ...	21	18	22
3 ...	29	24	35
Total ...	73	70	82

The plots were pollarded between the 9th and the 11th of November, 1949, and the shade was then erected as quickly as possible over the (*c*) series of plots. Chupon regeneration had started by the middle of December, and weekly counts of chupons and capsids were begun on 28th December, 1949.

The following table gives the sums of the number of bugs counted each day for the fourteen weeks up to 31st March, 1950 :—

TABLE 16.

Blocks.	Treatments.		
	(*a*)	(*b*)	(*c*)
1 ...	0	24	0
2 ...	7	85	6
3 ...	32	446	191
Total ...	39	555	197

It is clear from the table that the sum of capsid observations is much higher, and consistently higher in the unshaded plots than in the artificially shaded plots. Such a difference may be due :—

(*a*) to a larger number of chupons in the unshaded plot ;

(*b*) to differences in the degree in which capsids are attracted to the respective plots ;

(*c*) to differences in build up in the local populations after the immigration of adults.

The number of chupons is not the determining factor as is shown in the following tables which give the total number of chupons (greater than 2 in. long) which developed in the different plots during the fourteen weeks.

TABLE 17.

Blocks.	Treatments.		
	(*a*)	(*b*)	(*c*)
1 ...	23	264	275
2 ...	18	145	232
3 ...	11	274	235
Total ...	52	683	742

The date of invasion, as estimated by the appearance of lesions, is shown in the first column of the next table, and based on the appearance of bugs in the second.

TABLE 18.

Blocks.	Treatments.					
	(*a*)		(*b*)		(*c*)	
	(i)	(ii)	(i)	(ii)	(i)	(ii)
D2	15/2	—	18/1	8/3	—	—
D3	5/1	19/1	5/1	23/2	12/1	2/2
G	30/12	6/1	30/12	20/1	30/12	6/1

While it is difficult to draw definite conclusions from the limited data, there does not appear to be a consistent invasion earlier in one type of plot than in any other. Such differences in total population as have appeared above therefore must be due to differences in build-up after invasion. This is borne out by the weekly figures which show a steady increase in the unshaded plots after the first adults have entered

It is suggested that the observed differences can best be explained by the differential behaviour of the fertile female with regard to light.

Survey of the Conditions Associated with Capsid Damage.

The experimental results just discussed suggest that two factors may affect the distribution of capsid attack, viz. the nature of the canopy and the type of shade. To obtain quantitative data on the degree of association between capsid incidence and those two factors, a survey of the chief cacao growing areas of the Gold Coast has been conducted and was concluded in March, 1950. All parts of the Gold Coast belt were visited and capsids were collected wherever possible. At the same time, detailed observations on the nature and intensity of capsid injury were made and details of the growth conditions of the cacao were recorded according to a pre-cast questionnaire. The data now await analysis.

Regeneration of Capsid Pockets.

All the coppiced trees in the Capsid Regeneration trials are in excellent condition. These trees were coppiced late in 1946; in 1949, three years after treatment, the trees in two out of the three pockets treated were bearing pods. In the third pocket although the trees are regenerating well no pods have matured so far.

The control pocket, which was not coppiced but which has been sprayed at fortnightly intervals with nicotine sulphate (0·1 per cent.), shows no sign of improvement whatsoever.

A site has been selected for a larger field trial.

Sample Size—Adonkwanta Seedling Plot.

As a guide to future sampling it was decided to examine the distribution of capsids over a wide, fairly homogeneous area and for this purpose the unpainted seedling plot at Adonkwanta was selected.

A plot three chains square was selected for its apparent uniformity and all the occupied picquets in the plot were numbered. On the 29th December, 1949, a count was made of the number of capsids (*S. singularis* and *D. theobroma* only) per picquet.

The following table gives the observed frequency distribution and, in the second column, the frequency estimated on the hypothesis that the distribution would be fitted by a negative binomial distribution.

TABLE 19.

Bugs per tree.	Observed frequency.	Estimated frequency.
0	1,003	1,004
1	43	40
2	17	17
3	10	9
4	4	6
5	11	12
Total ...	1,088	1,088
	$X^2 = 1{\cdot}087$	
	P = 0·95 0·99	

The number of seedlings necessary to give an estimate of the population within 5 per cent. and 10 per cent. of the true mean was calculated and proved to be 900 and 700 respectively, not much smaller than the original number taken.

However, even within the " apparently uniform " area taken, it was possible by critical examination to select areas more liable to capsid attack than others, and it is therefore probable that, by careful classification of the cacao sampled, a sample size much smaller than the above could be truly representative.

Damage Resulting from Capsid Attack.

Mature Cacao.

Towards the end of 1946 part of one of the Individually Recorded plots on the Old Station was severely attacked and damaged by capsids. Many of the trees did not recover and the formation of a capsid pocket was rapid.

The Division of Agronomy has continued to record the yields and an examination of them gives a good indication of the reduction of crop which can be expected to follow the development of a capsid pocket.

For the purposes of the experiment mentioned above all the trees were classed early in 1947 as (*a*) Healthy, (*b*) Slightly Damaged and (*c*) Severely Damaged. The number of pods harvested per 100 trees from the various categories for the next three years is given below.

TABLE 20.

REDUCTION IN YIELD FOLLOWING THE FORMATION OF A CAPSID POCKET.

Number of pods per 100 trees.

Crop Year.	Severe damage.	Slight damage.	Healthy.
1946	2,107	1,920	1,963
1947	401	1,060	1,778
1948	130	1,150	2,900
1949	570	2,067	3,160
Total for 1947–49 ...	1,101	4,277	8,838

Young Cacao.

Late in 1948, an area of $1\frac{1}{4}$ acres was planted with large " basket seedlings " of the selection N38 for observations on possible resistance to capsid damage and *Calonectria* die-back. In March, 1949, the plants were examined with the following result.

TABLE 21.

	Number of seedlings.	Percentage of total.
Healthy	272	33·2
Slight Damage ...	384	46·8
Severe Damage ...	86	10·5
Dead	78	9·5

These are the only young cacao plants on the station to which routine capsid control measures are not applied and the figures quoted furnish striking evidence of the mortality to be expected in farmers' cacao in this district if control measures are not adopted.

Forest Reserve Cacao Plots.

The two plots in the Pra Anum Forest Reserve were visited in November, 1949.

Planted as seed at stake in August, 1946, the trees in the lower plot show variable growth owing to the different soils present, but, in about one third of the half-acre, they are 9 to 12 feet high and are producing flowers. In the upper plot the tallest trees are 12 to 15 feet tall with a thick, closed canopy.

The damage caused by *D. theobroma*, reported last year, has healed into scarcely visible cankers and neither capsids nor fresh damage were seen. Small colonies of *P. njalensis* were fairly common and considerable numbers of cacao psyllids were found on the flush shoots of the trees in the lower plot, but the latter insects did not appear to be having any permanent harmful effect.

Chemical Control.

Ant Attendants on Mealybugs.

Seven blocks of cacao were selected for experimental comparison of various treatments for the control of ants in attendance on mealybugs. Each of the blocks contained seven full rows of twenty-one trees separated from each other by incomplete rows of eleven trees. One of the following treatments was applied to each complete row, selection being at random :—

1. Grease banding (Material A).
2. Grease banding (Material B).
3. 10 per cent. D.D.T. dusting powder applied to the ground around the base of the tree.
4. 2·5 per cent. D.D.T. painted on the lower stem.
5. 5 per cent. D.D.T. painted on the lower stem.
6. 0·125 per cent. Parathion I (wettable powder) as a spray.
7. Control untreated.

All trees received the routine D.D.T. treatment on the upper parts of the tree as a capsid control. A collection of the ants present was made before the experiment started and they were arranged generically. Collections were also made one, two and four months after treatment with the following results :—

TABLE 22.

PERCENTAGE NO. OF TREES WITH "ATTENDANT" ANTS.

	Treatment.							Remarks.
	Grease Band A.	Grease Band B.	10% D.D.T. dust.	2·5% D.D.T.	5% D.D.T.	Para-thion.	Control	
March	5·7	5·7	5·7	5·7	5·7	5·7	5·7	Before treatment
April ...	0·9	0·4	2·1	2·3	2·4	1·9	5·4	After treatment
May ...	3·4	2·2	3·4	6·6	3·3	5·8	7·8	,,
July ...	2·8	1·6	2·1	2·0	4·0	3·2	4·9	,,

The percentages are weighted to facilitate comparison.

All treatments showed some success and it is proposed to repeat this experiment in greater detail.

Capsids—Laboratory Investigations.

The problem of measuring the toxicity of D.D.T. deposits to capsids has been approached by several methods. In all methods, varying types of cacao tissue coated with a D.D.T. deposit have been exposed to capsids in a 3½ in. diameter Petri dish, using three to six bugs in each experiment.

The D.D.T. deposit has been presented on :—

(*a*) one inch diameter plugs of pod cortex, taken with a cork border, and mounted in holes in a cork slab. Five of these plugs were used in each Petri dish.

(*b*) three-inch lengths of painted chupon ; and

(*c*) leaf surface of hardened flush.

The area of D.D.T. deposit in each dish was the same in (*a*) and (*b*) and equal to about 4 square inches. In spite of the many variable factors interacting in the experimental techniques, consistent results have been obtained. Where the insects made only intermittent contact with the insecticide film (1 per cent. D.D.T. emulsion) the action was slow and in 24 hours a consistent mortality of only 25 per cent. was obtained, using both *Bryocoropsis laticollis* and *Sahlbergella singularis* adults, though by this time most of the insects showed symptoms of D.D.T. poisoning. Constant contact gave a figure of 85 to 100 per cent. after the same exposure.

In connection with the work on insecticide films on pods, the following was used for calculating the liquid-holding capacity of the pod surface. The usual D.D.T. emulsion was made up with standard solution of sodium carbonate and the pod was rapidly painted and allowed to drain. When all surplus emulsion had drained off, the pod was washed with distilled water and the washings were collected in a clean beaker and titrated against hydrochloric acid, using phenophthalein as indicator. Consistent results were obtained and it was found that with unripe pods about 14 c.m. in length, an average of 0·25 cc. of emulsion was retained by the whole pod surface, with a maximum of 0·35 cc. These figures represent 2·5 and 3·5 milligrams of D.D.T. respectively, or approximately 8·25 to 10·6 milligrams per square foot of pod surface.

A comparison has been made between Toxaphene and D.D.T. at a strength of 1 per cent. each. Large test-tube culture cells were used and the insects were confined on painted twigs for a period of 18 hours, from 3 p.m. to 9 a.m. Experiments were carried out on nine separate days and a total of 248 fourth and fifth instar nymphs, mostly of *Sahlbergella singularis*, were used. The results were strikingly in favour of Toxaphene which gave a mean 18 hour mortality, corrected for untreated control mortality, of 68·4 per cent., while the figure for D.D.T. was 42·8 per cent. It is intended to continue this experiment on seedlings in the field to investigate residual action and the possibility of fumigant action affecting the laboratory experiment. A single trial on seedlings in an insectary produced figures of 76·3 per cent. and 43 per cent. which agree well with the laboratory results.

Comparative Toxicity of new Formulations.

Several new formulations of D.D.T. and Gammexane have been received and they have been compared with the normal 2·5 per cent. D.D.T. emulsion which is used as a control for capsids on young cacao.

A two acre plot of young cacao (18 months old) was divided up into 20 smaller plots each containing 54 trees.

The treatments were :—

1. 2·5 per cent. D.D.T., made by diluting a 50 per cent. oil bound suspension of D.D.T.

2. 0·3 per cent. Gammexane, made by diluting an emulsion containing 6·25 Gammexane.

3. 0·3 per cent. Gammexane, made by diluting a solution containing 6·15 per cent. Gammexane. In the diluted solution the Gammexane was present as a fine suspension.

4. 2·5 per cent. D.D.T. emulsion, used as a standard.

5. Control. No treatment.

Four small plots, selected at random, were used for each treatment and for the control. Four months after treatment a count was made of all the trees for capsid damage with the following results :—

TABLE 23.

Treatment.	Number of damaged trees.	Percentage showing damage.
Control	45	20·7
2·5% D.D.T. emulsion	11	5·1
2·5% D.D.T. crystalline suspension ...	24	11·2
0·3 Gammexane suspension...	9	4·2
0·3 Gammexane	1	0·5

Whilst this experiment has not gone on long enough for the results to be conclusive, it is most interesting to note the extremely good results obtained with the Gammexane emulsion. These results are much better than those obtained earlier with benzene hexachloride preparations. A certain amount of scorching on young growth was observed with both of the Gammexane preparations but it was not serious.

Capsid Pocket Recovery.

In February a large silk cotton tree fell into an area of healthy, mature cacao and caused considerable damage. In May, 1949, one section containing twenty-five damaged trees was sprayed with 0·5 per cent. D.D.T. wettable powder while the other section containing eighty trees was left as a control in the hope that it would develop into a capsid pocket. This did happen and now the control section is a mass of dead or dying trees through the activity of capsids and the fungus *Calonectria*

rigidiuscula. The treated side, where treatment was repeated in September, 1949, and January, 1950, with 1 per cent. D.D.T. wettable powder, shows scarcely any damage and the trees have sent out new growth and appear to be healthy in every way.

This treatment can be compared with that in another pocket nearby which has been receiving fortnightly sprayings with 0·1 per cent. Nicotine sulphate over the last three years. There has been no improvement in this pocket.

Two other potential pockets on the Old Station have been treated with 1 per cent. D.D.T. wettable powder and results are awaited.

A well defined pocket, containing in all sixty trees, has been selected and fifteen trees treated with 1 per cent. D.D.T. emulsion and fifteen treated with 0·3 per cent. Gammexane. The remaining thirty are kept as controls.

The chemical is applied by means of a very fine jet, developed at Tafo, which can apply a small quantity of insecticide on the branch unions and forks. This results in a great saving of chemical compared with normal spraying, and by placing the insecticide where it will be most effective it is hoped that a satisfactory control will be achieved.

The use of Smoke Generators.

A series of experiments is in progress to investigate the possibility of using smoke generators for treatment of mature cacao with insecticides. The experiments, at this stage, are concerned only with the behaviour of smokes in the open and do not take insecticidal action into account.

A number of observations has already been made during the dry season and will be continued into the rainy season.

The object of these observations is to establish whether, at any time during the day, suitable inversion conditions occur. With this end in view readings are taken of temperature about two feet above ground level and in the cacao canopy. Values for Relative Humidity are also recorded. At the same time smokes are released and their behaviour is noted. These observations are made at dawn (06.00 hr. approx.), in the midday heat (14.00 hr. approx.) and at dusk (18.00 hr. approx.).

Certain conclusions have been made covering the dry season. These may be grouped as under :—

Dawn. Temperature has varied from 65° F. to 70° F. with no difference detectable between ground and canopy, with the apparatus available. Relative Humidity has been above 90 per cent. Smokes released have risen vertically and passed straight through the canopy. They have then continued to rise vertically or have rolled along the top of the canopy for a short distance before rising. On a number of occasions the smoke, having risen to a height perhaps of over 100 feet, has come down again and entered the canopy, presumably as a result of being cooled in some upper layer. Advantage cannot, however, be taken of this phenomenon since the precise location where the smoke descends is quite unpredictable. These observations make it clear that the use of smokes at dawn is not feasible.

Midday Heat. Temperature has been 90° F. with only slight variation and again no difference was detectable between ground and canopy. Relative Humidity has varied from 45 per cent. to 70 per cent. approximately. During the dry season there is always air movement during the day which may attain conditions of gustiness. If gusts are present the use of smokes is impossible. With gusts absent, released smokes have drifted under and within the canopy. The direction of drift, however, changes rapidly and a smoke cloud may change direction through 270° within one minute. On some occasions, where there has been a relatively large opening in the canopy, the cloud has risen vertically. Under these conditions the use of smokes is again not feasible.

Dusk. Temperature has varied from 70° F. to 85° F., with no difference detectable between ground and canopy. Relative Humidity has varied from 60 per cent. to 85 per cent. The air at this time of day is usually still. Released smokes have gone into the canopy and drifted within it. The drift has generally been extremely slow. Good coverage has been obtained by placing the smoke generator in a carrier and having the operator walk along beneath the trees. It would appear that an inversion takes place and that conditions suiting the use of smokes do occur. This statement must, however, be qualified by the fact that the change from non-inversion to inversion conditions seems to take place rapidly and without any obvious signs. It therefore requires an operator sufficiently skilled to recognise the point at which conditions become favourable. Although farmers could not be expected to possess this skill, the fact remains that at this time of day, conditions under which the use of smokes may be feasible, have been shown to exist.

Spraying and Dusting Machinery.

Todd Insecticide Fog Applicator ("TIFA").

The machine produces a large volume of insecticidal fog which is forced out through the nozzle by means of a high capacity air blower. It was thought at first that the conditions on cacao farms might prove ideal for this type of machine, but the various tests carried out at two different times (mid-August and mid-November) were most disappointing. The fog blown from the slowly moving machine penetrated the cacao for 50 to 60 feet and then rose vertically. After penetrating the canopy, the fog levelled off and could be seen drifting above the canopy.

Apparently the conditions under the cacao canopy are too still to ensure a reasonable drift of the fog.

The tests were carried out at daybreak, midday and evening and there was little, if any, difference in the behaviour of the fog cloud at the various times of the day.

Thanks are due to the manufacturers for the loan of this machine.

Portamist Sprayer.

This machine consists of a 1 h.p. motor coupled to an efficient fan giving a good air blast. The insecticide is injected into the air-blast by means of a small liquid pump and is split up into a finely divided spray which travels a considerable distance under its initial impetus.

The machines are still under test but they behave reasonably well in the field. The greatest trouble has been experienced with the motors, which have required frequent repair.

Hi-Fog.

This is an American machine which produces a very finely divided spray. It consists of a knapsack-type cylinder which is charged with non-expendable nitrogen at 350 lb. per sq. in. and into which the insecticide is pumped against a movable piston by means of a small hydraulic pump. The movement of the piston further compresses the nitrogen and when just over three quarts of insecticide have been introduced the pressure is around 950 lb. per sq. in.

An extensible lance is provided and in operation an extremely fine mist is produced at the rate of one quart every five minutes.

The high cost of this machine renders it more of a laboratory instrument than a field appliance.

Dusters.

"*Midget.*"

The machine consists of a small 34 cc. motor and fan which is carried by the operator on his chest. The fan is connected by a flexible alloy pipe to the dust hopper which is carried on the back. A good volume of dust is produced. Ten to fifteen lb. of 10 per cent. D.D.T. dust per acre has been the normal dosage used and, given good dusting conditions, this quantity appears to give a reasonable control of capsids. This machine is a recent production and its performance could be improved by minor modification of certain details. The manufacturers have been informed and various small modifications have been carried out at Tafo.

Pestmaster.

This is a self-propelled dusting machine, of larger capacity than the "Midget" described above. It was received on loan from the Department of Agriculture, Gold Coast, in February, 1950. Preliminary tests were not very successful but it is hoped that, by making several minor modifications, considerable improvement will be obtained.

IV. SOIL SCIENCE.

Influence of Deficiency and Excess of Major Nutrients on Growth and Mineral Status of Young Cacao Plants.

The details of this experiment with young cacao grown in sand culture were given in the Annual Report for 1948-1949. From measurements of growth, including number and area of leaves and length and diameter of stem, the following conclusions can be drawn.

Deficiency of phosphorus depresses the plant growth, and especially the development of foliage, to a much greater extent than does a deficiency of potassium or of nitrogen. On the other hand even a large excess of phosphorus does not affect the growth of plants, whereas excess of nitrogen and potassium is highly detrimental to the development of both foliage and stem. Plants which had been treated with an excess of potassium or nitrogen declined rapidly after six months, while those grown in solutions deficient in one or more nutrients, although stunted, survived longer. Simultaneous increase of the concentration of all nutrients, with their relative proportions unchanged, has a highly injurious effect on plant growth. In all cases, when nutrients were applied in excess, whether singly, in pairs, or all at the same time, very severe symptoms of physiological distress have developed on leaf tissues. It appears that a high concentration of ions in the growing medium affects much more strongly both the growth and the health of plants than does the change in their respective ratios or their deficiency.

The Nutrient Content of Leaf Tissues.

Estimations of potassium and phosphorus in fresh leaves of experimental plants were carried out, using the cobaltinitrite method and colorimetric method respectively. Nitrogen was determined by the Kjeldahl method in air-dry leaves and recalculated on a fresh tissue basis. The content of nitrogen, phosphorus and potassium in the plants grown in complete NPK solution was adopted as standard.

(*a*) Nitrogen content in leaf tissues differed markedly from that in the standard only when the element was deficient in the nutrient solution ; otherwise it remained remarkably steady, even when present in greatly increased concentration in the nutrient solutions. Nevertheless, the signs of interveinal necrosis appeared whenever nitrogen was in excess, which would indicate that it is the increased concentration of the element in the growth medium and not in the tissues which caused the physiological changes in the leaves.

(*b*) The potassium content, contrary to that of nitrogen, increased considerably in leaf tissues with increase of the element in nutrient solution, and was always accompanied by severe symptoms of " K excess " (brown spots near the midrib).

(*c*) Phosphorus was highly mobile and its content always increased whenever its concentration in the solution was increased. Its increase in leaf tissues always accompanied the excess of potassium or nitrogen, even when the element remained at the normal level in nutrient solution.

NPK Experimental Plots with Young Cacao.

The experiment, initiated in 1942 and described in previous reports, had to be abandoned owing to extremely uneven growth, consequent upon lack of soil uniformity and severe capsid damage. The measurements, however, of trunk diameter were taken and analysis of variance

showed a certain statistically significant promotion of growth by superphosphate and depression of growth, nearing significance, caused by sulphate of ammonia :—

Treatments.	Variance.	F.
N	3·511	2·9081
P	4·205	3·4827
Error ...	1·207	—

The differences between other treatments were not significant.

Organic Carbon and Total Nitrogen Content of Surface Soils.

A plot of land was stumped and cleared of all vegetation. Three months later, the organic carbon and total nitrogen content of the soils in this plot were compared with those of nearby soils under forest. The mean values for these determinations are shown in the following Table :—

TABLE 24.

	Per cent. Organic C.	Significant difference.	Per cent. N.	C/N.	Significant difference.
Plots ...	0·762		0·087	8·877	
Forest ...	1·496	0·279	0·163	9·16	0·289

It is evident that, after three months of exposure to direct sunlight, a very marked decrease of organic carbon and of total nitrogen occurred in the soil. The latter was relatively slower, so causing the decrease of the C/N. ratio.

V. CHEMISTRY.

Organic and biochemical work has been continued on the various projects outlined in the previous year's Annual Report and the scope extended where preliminary results warranted it.

1. *Butter-fat and Alkaloid Extractions.*

Surveys of the above constituents are in progress, using unfermented oven-dried beans of *T. cacao*, in connection with the following projects :—

A. Variation within apparently uniform *T. cacao* populations.

B. Seasonal variation.

C. A comparison of healthy beans and those taken from pods infected with *Phytophthora palmivora* Butl.

D. Comparison of methods of extraction for butter-fat.

Experimental procedure was similar to that described in the Annual Report for 1948-49.

A. *Variation within* T. cacao *populations.*

The three populations chosen were

(i) West African Amelonado ;

(ii) The Amazonian type Parinari × Nanay.

(iii) Clonal material—TF2—comprising Trinitario trees of unknown parentage, all bearing yellow pods.

Analyses have been completed in (i) only, where five pods were harvested over a six-week period from each of ten different trees, growing on the same well-drained sedentary soil developed from grandiorite granites and under similar cultural conditions.

Results may be summarised as follows :—

TABLE 25A.

Bean constituent.	Population No.	Mean per cent.	Sample size to give an estimate within 1% of true population mean at P = 0·05.
Butter-fat ...	50	53·16 ± 0·168	20
Total alkaloids...	100	2·91 ± 0·040	190
Theobromine ...	100	2·58 ± 0·041	247
Caffeine... ...	100	0·33 ± 0·010	882

TABLE 25B.

Tree No.	Mean per cent. butter-fat.	Comment.
CD 7	54·86	Group I
,, 6	54·16	
,, 10	53·90	
,, 9	53·89	
,, 5	53·78	
,, 4	53·07	Group II
,, 2	51·86	
,, 1	51·47	Group III
,, 3	50·99	
S.E.	±0·4554	
Signif. diff.	±1·30	(P = 0·05)

TABLE 25c.

Tree No.	Mean per cent. Total alkaloids.	Comment.
CD 4	3·39	Group I
,, 2	3·35	
,, 10	3.20	
,, 7	3·03	
,, 3	2·84	Group II
,, 6	2·82	
,, 8	2·79	
,, 9	2·50	Group III
,, 1	2·25	
S.E.	±0·127	
Signif. diff.	±0·3568	(P = 0·05)

The above statistical analyses indicate that, in the apparently homogeneous West African Amelonado population,

(i) The differences between the butter-fat and alkaloidal constituents in beans from *different trees* are greater than those from beans within any tree.

(ii) Significant butter-fat differences are shown to exist, apparently falling into three groups (cf. Table 25b).

(iii) Significant total alkaloid differences also appear to exist (cf. Table 25c).

(iv) The sample size for the estimation of butter-fat is satisfactory.

B. *Seasonal Variation.*

Four pods were harvested at random from the Square Mile every fortnight throughout the year. Ten beans were removed from each pod and the bulked sample treated as described in the previous Annual Report. This experiment has been in progress for two years and results so far have indicated that the considerable difference in butter-fat content between main crop and light crop (5 per cent.) found by Doyne and Voelcker over a two year period at Ibadan, Nigeria (1), does not obtain at Tafo. At Ibadan there is a distinct dry season from November to March when the total rainfall does not exceed 5 inches, whereas the average Tafo rainfall for the above months in each of the last ten years, has been two-and-a-half times as much. Pods therefore set under advantageous conditions at Tafo when a comparatively low rainfall pertains at Ibadan. The main and mid-crop seasons at Tafo are not therefore clearly defined and the choice of time for division into these categories is purely arbitrary. The light crop is here assumed to be from March-July (inclusive) and on this

assumption the average butter-fat percentage during the main harvesting season and the light crop is as follows :—

TABLE 26.

Date.	Average per cent. butter-fat	Difference.	Total rainfall Nov.-Feb. (incl.).
March–July 1948 (incl.)	52·40	2·94	1947–8—8·68″
Aug. 1948–Feb. 1949 (incl.) ...	55·34		
March–July 1949 (incl.)	53·31	0·77	1948–9—13·58″
Aug. 1949–Feb. 1950 (incl.) ...	54·08		

The variation in total alkaloid and theobromine content has tended to follow, in the main, a similar course to butter-fat variation. Caffeine content appears to be highest when the butter-fat, total alkaloid and theobromine content are at their lowest.

The experiment will be continued for a further two year period during which it is proposed to vary the harvesting procedure and a full discussion of the results is reserved until completion of the project.

C. " *Black-pod* " *Cacao.*

Reports from various Experimental Stations in Nigeria over the past twelve years indicated that as much as 30 per cent. of the annual crop has at times consisted of diseased pods which were, in the main, infected with " black-pod " disease. It is not at present possible to obtain an accurate estimate of the total loss of pods per annum due to " black-pod " in the Gold Coast or Nigeria but on the assumption that the various experimental station figures have a general application, the annual loss can be reckoned in thousands of tons.

As a result of some preliminary experiments in 1941–2 it was reported by West (2) that the percentage of butter-fat in infected beans was higher than that of healthy beans whilst the free fatty acid content of both categories remained the same. It was decided to investigate the problem in more detail as the waste pods might well be used as a source of edible oil.

Random harvesting of diseased pods in the Square Mile was carried out during the 1949 heavy rains and in all instances a healthy pod was harvested from the same tree as the diseased pod ; the butter-fat, alkaloidal and free fatty acid content of all pods were examined. From preliminary experiments, involving inoculation of ripe pods in the laboratory with *Phytophthora palmivora* Butl. and examination at various intervals, it was obvious that there were varying stages of infection, irrespective of the external appearance of pods. For the present experiment a bean was considered to be diseased which, when planted, would not germinate and in order to assess this possibility, infection of the radicles was easily detectable. The experiment is still in progress.

D. *Comparison of Butter-fat extraction methods.*

Seven samples which had previously been analysed by the method described in the Annual Report for 1948-49 were re-examined using two procedures :—

(i) The Hydrochloric acid method of the International Office for Cocoa and Chocolate.

(ii) A method using short extraction periods, each followed by grinding of the sample with sand.

From the results tabulated on page 52 it is seen that the method used at W.A.C.R.I. removes a higher percentage of butter-fat than the other methods and must be considered the most reliable of the three. Although the time required to complete a single analysis using the " W.A.C.R.I. method " (which is essentially based on the method of Humphries (3)), is greater than that for either of the other two, it is justified for our purposes by the greater accuracy achieved.

2. (*a*) *Incidence and Distribution of Tannins in* T. cacao.

This investigation was initiated as a result of the plant pathological finding that the various strains of the swollen shoot virus complex cannot be sap transmitted. As plant extracts containing tannins are known to be efficient protein precipitants and equally efficient virus inactivators in virus diseases which are known to be sap transmissible, *e.g.*, tobacco mosaic, it was considered that an examination of the distribution of tannins and tannin-like compounds in *T. cacao* seedlings would be a useful preliminary to further experiments on sap transmission and other problems associated with the swollen shoot virus.

The method of estimation used ensured the extraction not only of the tannins which were soluble in 40 per cent. acetone, but also of the more condensed and insoluble tannin compounds. The two main conclusions which emerged from a comprehensive series of preliminary experiments are as follows :—

(*a*) Drying the various tissues of *T. cacao* seedlings at 105° C. for 20 hours causes an increase in the total percentage of extractable tannins of $0{\cdot}985 \pm 0{\cdot}040$, irrespective of tissue and for all practical purposes may be regarded as 1 per cent.

(*b*) No prior inactivation of the oxidizing enzymes is necessary before drying the tissues.

Dried material was used in the ensuing tannin distribution experiment to facilitate analyses during the early harvests and to increase the speed of determinations (as a result of the absence of mucilage in the extracts).

T. cacao seedlings were grown under uniform conditions and equal numbers were harvested at set periods, each harvest being divided into five groups. Estimations were carried out on all samples using the dried material from 25 grm. fresh weight and all were done in duplicate. Final results are not yet available.

TABLE 27.

Source of Material.			Date of Harvest	Total per cent. Butter-fat		Per cent. Butter-fat by method used at W.A.C.R.I.		
Plot No.	Stand No.	Selection.		HCL Method.	Sand-grinding method.	Light Petroleum Extract.	Chloroform Extract.	Total
J 94	34	N 38	1/11/48	53·26	52·69	52·28	2·02	54·30
Bulked sample of W.A. Amelonado cacao from Square Mile...			1/3/48	52·42	49·14	50·74	1·76	52·50
Bulked sample of W.A. Amelonado cacao from Square Mile...			29/9/48	52·34	51·51	52·46	1·80	54·26
Bulked sample of W.A. Amelonado cacao from Square Mile...			13/10/48	52·39	52·85	54·64	1·02	55·66
Bulked sample of W.A. Amelonado cacao from Square Mile...			8/12/48	52·56	51·15	53·88	1·90	55·78
Bulked sample of W.A. Amelonado cacao from Square Mile...			13/4/49	50·93	49·52	50·16	2·44	52·60
Bulked sample of W.A. Amelonado cacao from Square Mile...			27/4/49	50·06	49·81	50·20	3·56	53·60

3. *Single-pod Fermentation.*

A method which has yielded very promising preliminary results, has been evolved for the fermentation of the contents of a single cacao pod. The details have been prepared for publication.

Uniformity trials are in progress on West African Amelonado and the Upper Amazonian cacao types. Assessment of flavour will be carried out in Great Britain.

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VI. BOTANICAL AND HORTICULTURAL STUDIES.

Propagation of Cacao by Cuttings.

Routine Propagation.

Cutting Material.

The type of cutting now employed for routine propagation differs somewhat from that hitherto used at Tafo and in Trinidad. The cutting is essentially of greenwood, with the lower part of the stem just ripening, and the leaves fully expanded but not hard. The length as ready for insertion is 8–10 inches ; all the leaves are retained and are not trimmed. Previously, the cuttings used were of ripened wood and were longer and it had been the practice to trim the leaves.

Cuttings of the semi-greenwood type have shown less premature leaf senescence in the propagating bins and consequently are more vigorous both during and after hardening.

Experimental work on Propagation.

(a) *Rooting media.*

The standard rooting medium, coarse washed river sand, is not completely satisfactory as it encourages the formation of brittle roots with a poor degree of fibrousness ; thus transplanting from the propagating bins to baskets always results in some loss of material. It has been found, in addition, that with sand there is often a lower temperature at the level of root formation than at the surface, a state which may well retard rooting.

Work is proceeding on the comparative testing of the following media in addition to coarse sand : (1) rotting oil palm trunk fibre, (2) palm fibre and sand in equal proportions, and (3) wood mould—obtained from around rotting felled trees. Results to date indicate the relative superiority of the palm fibre and sand medium.

(b) *The effect of light and/or temperature on rooted cuttings after hardening.*

Some weeks after vigorous rooted cuttings are placed in the plant-shed for acclimatisation they appear to lose vigour and the production of new growth is meagre. Tests have been made to investigate whether the heavy shade and consequent low temperature of the plant-shed are responsible for this.

As batches of cuttings were removed from the hardening bins, half of each batch was placed as usual in the plant-shed, and the remainder transferred to an insectary with about 50 per cent. normal light intensity and a mean temperature higher than that of the plant-shed. After 21 days the length of new growth and the number of new leaves per cutting were recorded. The results are given in Table 28.

TABLE 28.

NEW GROWTH 21 DAYS AFTER REMOVAL OF CUTTINGS FROM THE HARDENING BINS.

	Plant-shed.		Insectary.	
	1st batch.	2nd batch.	1st batch.	2nd batch.
Number of cuttings ...	15	20	15	20
Number of cuttings flushing	1	5	11	20
Av. total length of new growth	10 cms.	9·5 cms.	16·5 cms.	21·9 cms.
Av. number of new leaves per cutting ...	3	1·4	5·4	5·6

Following this preliminary test more detailed experiments have been started to ascertain optimum conditions of light and temperature for the rapid growth of cuttings after the hardening process.

(c) *Single leaf cuttings.*

Following the publication of results obtained in Surinam from the use of single leaf cuttings (Cacaowerk, Surinam, 1949), trials have been started to find out whether the technique is applicable under West African conditions.

In a preliminary experiment two types of cuttings, both from fan material, were used. These were (1) leaf-bud cuttings—consisting of a bud shield with a single complete leaf, and (2) " mallet " cuttings, consisting of 1 to 1½ inches of stem with a bud and its subtending leaf.

Greenwood and ripened wood cuttings of each type were used. The cuttings were treated with 0·5 per cent. B-Indolyl butyric acid in talc and set in coarse sand. Fifty cuttings were inserted in each propagating bin.

The cuttings were examined at 21, 31 and 50 days after insertion in the bins. The greenwood cuttings of both types were found to be greatly superior to those of ripened wood. The former were comparable with ordinary fan cuttings with regard both to time taken to "strike" and the final appearance of the root systems. The results are given in Table 29.

TABLE 29.

ROOTING OF "MALLET" AND LEAF-BUD GREENWOOD CUTTINGS

(50 cuttings of each type).

Type of cutting.	Potted after 21 days.	Potted after 31 days.	Potted after 50 days.	Total Potted.	Per cent. Potted.
Mallet ...	34	9	4	47	94%
Leaf-bud ...	6	14	19	39	78%

From these results it would seem that the mallet type roots more evenly and quickly than the leaf-but. During hardening, only one cutting of each type was lost. In a number of cases particularly with mallet cuttings, the bud began to proliferate while the cuttings were still in the hardening bin.

If subsequent growth of the mallet cuttings proves to be satisfactory the use of this type of cutting would be highly economical both of material and space. Mallet cuttings would be of great value in the rapid multiplication of desirable clones.

(d) *Herbaceous grafting.*

Successful unions have been obtained by means of herbaceous wedge grafts between immature shoots of established cacao trees and two-months old seedling stocks.

After grafting, the plants are kept under bell-jars until union is indicated by the callusing over of leaf-scars. A 75 per cent. success has so far been obtained.

Considerable care is required if bruising of the very soft tissues and wilting of the scion is to be avoided.

Progeny Trials.

First Progeny Trial (planted 1940).

Twelve plots in which fewer than a third of the trees are in bearing, have been abandoned for further botanical studies.

In the 1949–50 harvest season the selection E.1 was again first, with regard to both the total number of seedling progeny in bearing and the mean wet weight of cacao per pod. It is inferior to a number of others in the mean yield of pods per bearing tree, but is first with regard to the effective production of wet cacao per bearing tree.

TABLE 30.
SUMMARY OF THE 1949–50 YIELDS OF THE SIX BEST SELECTIONS.

Selection.	Number of bearing trees.	Total pods harvested.	Yield of pods per bearing tree.	Mean wet weight per pod.
E.1	106	1,725	16·3	4·3 ozs.
S.84	75	1,387	18·5	3·5 ,,
S.72	82	1,385	16·9	3·4 ,,
A.220... ...	83	1,354	16·3	3·4 ,,
A.187... ...	78	1,290	16·5	3·4 ,,
N.38	81	1,290	15·9	4·0 ,,

Second Progeny Trial (planted 1942).

In the 1949–50 harvest season the selection E.1 proved superior to the other selections with regard to the number of seedling progeny in bearing and the total number of pods produced, although it is again closely rivalled by the selection T.F.1 which actually exceeded E.1 in the amount of wet cacao produced.

TABLE 31.
SUMMARY OF THE 1949–50 YIELDS OF THE FIVE BEST SELECTIONS.

Selection.	Number of bearing trees.	Total pods harvested.	Yield of pods per bearing tree.	Mean wet weight per pod.
E.1	60	499	8·3	4·9 ozs.
T.F.1	55	449	8·2	5·0 ,,
B.2	44	417	9·5	3·6 ,,
A.45	34	395	11·6	2·6 ,,
K.5	36	388	10·8	3·4 ,,

New Introductions.

Yield figures for 1949–50 show that the Upper Amazon selections T.12 (Scavina), T.60 (Parinari × Nanay), T.63 (Parinari × Nanay) and T.79 (Nanay × Parinari) are again outstanding in yield, producing nearly twice as many pods as their nearest rivals and, on the average, thirty times as many as the highest yielding West African Amelonado, planted at the same time.

TABLE 32.

SUMMARY OF THE 1949–50 YIELDS OF T.12, T.60, T.63, T.79 AND T.F.15.

Selection.	Parentage.	Total trees.	Bearing trees.	Pods harvested.	Mean pod yield per tree.
T.12 ...	SCA12	24	24	813	33·9
T.60 ...	PA7* × Na32	20	20	827	41·4
T.63 ...	PA35 × Na32	27	27	1,028	38·1
T.79 ...	Na32 × PA7	28	28	901	32·2
T.F.15 ...	W.A. Amelonado	43	12	51	1·2

* PA7 and PA35 possibly sibs.

Pollination.

Self-pollination carried out on a number of the Upper Amazon selections indicated that there is probably a high degree of self-incompatibility amongst these types. Insufficient flowers were pollinated, however, for a final conclusion to be reached.

During the next flowering season intensive self-pollination will be carried out with a few high yielding sections to provide further data. Sib-intercompatibility will be tested in a similar way.

VII. MYCOLOGY.

During the past year, mycological work has had special reference to studies of pod diseases. An experiment on the control of pod diseases by chemical and other means has given very interesting results ; in particular, the efficacy of frequent harvesting as a means of control has been amply demonstrated. A basic pod disease investigation has been initiated, and should yield valuable records, especially after several years. The parasitism of *Calonectria rigidiuscula* (Berk. & Br.) Sacc. has been further studied in certain aspects. A new line of work has been commenced—experiments on the biological control of mealybugs by fungi—and laboratory experiments with a species of *Aspergillus* have given interesting results.

Pod Disease Control.

Details of this experiment, which was set up in 1948 to examine the effect of various treatments on incidence of pod diseases and damage caused by them, have already been given (Annual Report 1948–49). Records for the first year of the experiment, given in that Report, showed that while incidence of pod diseases (especially " black pod " disease, caused by *Phytophthora palmivora* Butl.) was reduced by certain treatments, notably fungicide spraying, none of the treatments influenced the mean weight of wet beans per pod. The latter figure is of greater importance from an economic viewpoint than the percentage of pods infected by any particular fungus, since many infected pods give a full yield of good beans.

Records from the 1949–50 crop season, however, show rather different results. At the beginning of the season, weather conditions were favourable to the spread of black pod disease and an epiphytotic developed. It was then believed that the season would prove to be a "bad black pod year" and that differences between the various control measures would be the more conspicuously exhibited. In fact, however, the epiphytotic was scarcely noticeable in the experimental plots; the mean percentage of pods infected with *P. palmivora* in the control plots over the season was 14·6, compared with 12·5 per cent. for the 1948–49 season. Doubtless the explanation of this effect is mainly to be found in the topography of the experimental area, which is fairly elevated and, while gently sloping, has a uniform gradient without streams or low-lying pockets; shade and tree density, moreover, are by no means excessive.

The results tabulated below were obtained from harvests between 23rd June, 1949, and 12th January, 1950, covering practically the total crop. The analysis of records of diseases other than black pod are not presented here, as they are of minor significance, and the incidence of these other diseases is largely dependent upon a variety of factors causing mechanical damage to pods. In general the trends are similar to those shown in relation to black pod disease, but differences between treatments are not so marked, which is to be expected. Results from the nicotine sulphate-spray plots are likewise omitted: they were not significantly different from those relating to the controls.

The mean percentage of pods infected with *Phytophthora palmivora* in each treatment is shown in the table below. Significant differences are indicated by broken lines. The means shown are the de-transformed percentages, the angular transformation having been used to convert the original percentages for the analysis of variance.

TABLE 33.

Treatment.	Mean No. of black pods (per cent.).
Control	14·6
Weekly harvesting	11·5
Spraying with Perenox	2·7
Spraying with Bordeaux mixture	1·9

The next table gives the mean weight of good wet beans per pod for each treatment.

TABLE 34.

Treatment.	Weight of wet beans per pod (oz.).	Significance of Difference.
Weekly harvesting ...	3·81	Significant
Bordeaux spray ...	3·50	
Perenox spray ...	3·58	Significant
Control	3·32	

It is clear from Table 33 that a very considerable control of *P. palmivora* infection was obtained by spraying with fungicides. The degree of control was much greater than in the previous season (mean percentage of black pods in Bordeaux mixture-sprayed plots 1·9, compared with 4·5 per cent. for 1948–49 season), probably due to diminished numbers of cushion infections as a result of the first year's spraying.

There was little diminution in black pod disease incidence in the weekly harvested plots compared with the controls, though the reduction was statistically significant. However, it will be noted that weekly harvesting gave the greatest mean weight of good wet beans per pod—significantly greater, not only than the control figure, but even than that from the plots sprayed with Bordeaux mixture: yet spraying with Bordeaux mixture resulted in the lowest incidence of black pod disease.

With Perenox spraying, the mean weight of good wet beans per pod was not significantly different from the weekly harvesting result, but significantly greater than the control figure. The Bordeaux mixture treatment gave a difference in mean weight from the control treatment which just failed to reach significance at P=0·05. This failure, and the generally high variation throughout the experiment, may in large part be ascribed to the extensive and sporadic distribution of squirrel damage over the area.

The superiority of weekly harvesting over other treatments, with respect to mean weight of good beans per pod, is of considerable interest and shows that the control so frequently recommended for black pod disease gives the results claimed for it.

In this experiment the sprays have been applied every week. This frequency could probably be greatly reduced without affecting the results. Even so, however, the cost of spraying would probably be very much greater than that of weekly harvesting, though admittedly this would be to some extent offset by the reduced frequency of harvesting which could be permissible as a result of spraying, and it would be very much more trouble in every way.

These experimental results stress the value of weekly harvesting.

Fundamental Work on Pod Diseases.

Comprehensive Pod Classification Investigation.

This study, which is intended to continue for several years, was started at the beginning of the 1949–50 crop season. The object is to obtain an estimate of the extent of pod damage and of the loss caused by various agents and of their relation to season, situation, etc., as well as to obtain information on such points as the degree of correlation of one particular type of damage with another (*e.g.*, of mealy pod disease with rodent damage).

Eight plots of mature cacao, one-eighth acre each, were selected in the Old Station. Plots were first picked at random, but this resulted in what was, for the greater part, a rather uniform assemblage of plots

under mediocre cacao, and it was decided to abandon the principle of randomisation. Eight plots were accordingly chosen to cover the range of environmental variation in the Old Station cacao as well as possible.

At the time of picking, each pod is given a serial number, which is recorded together with the number of the tree and the site of the pod, *i.e.*, branch, upper or lower trunk. Cherelles are disregarded.

In the laboratory the pods are examined carefully and a record is made of the occurrence of black pod, mealy pod, brown pod and warty pod diseases, and of *Helopeltis* and other capsid damage, rodent and borer damage, also of whether the pod is mature or immature. If the pod is completely discarded a note is made of the probable primary cause.

The contents of the pod are weighed, the wet-weights of good and of bad beans are recorded separately to the nearest gram.

To be brought into operation at the commencement of the second year of the investigation, a slight modification has been made to the field record sheets, four additional categories of damage having been added : (*a*) *Fusarium* spp., (*b*) scale insects, (*c*) mechanical damage and (*d*) unidentified. (*a*) Several *Fusarium* species occur as weak wound parasites on cacao pods, and are responsible for some loss. Scale insects stunt the growth of a pod if a heavy attack occurs early in the development of the pod, and may also cause malformation. A considerable amount of mechanical damage occurs through the harvesting knife slipping and making small cuts in the husks of pods which are not ready for harvesting. These small wounds often become infected by fungi, especially *Trachysphaera fructigena* Tab. & Bunt. (mealy pod disease). During the past season mechanical damage was not recorded and the records thus appear to indicate the occurrence of mealy pod disease without preceding mechanical injury, which was certainly not the case in most instances. It was found necessary to record unclassifiable rots and types of damage rather than attempt to classify them, possibly incorrectly.

In the accompanying table is presented a summary of the principal records for the months of July to December, 1949, inclusive, during which over ninety per cent. of the season's crop was harvested.

Black pod disease was of overwhelming importance. A majority of pods was attacked by *Helopeltis* sp., but most of this damage was relatively slight and confined to the outside of the husk.

Harvesting was carried out at weekly intervals after the end of July, owing to the high rainfall in late June and July, and the resulting high incidence of black pod disease. It will be seen that losses of pods, mainly due to black pod disease, were much lower in September than in July and August, although the September rainfall was higher (8·84 ins.) than that of August (4·37 ins.). That is, the initiation of weekly harvesting checked the spread of the disease, though not at once. The proportion of immature pods harvested was higher in August than in July, but was only a little lower than the percentage discarded, so that although more pods were infected with *Phytophthora palmivora*, damage was to a greater extent limited to the younger pods. After August the proportion of

immature pods harvested fell rapidly, and reached zero in December, showing that by the end of the year fungus diseases became of little significance; attacks on more or less mature pods seldom affect the beans.

TABLE 35.

	Month.					
	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Total number of pods ...	1,397	1,621	3,696	2,954	2,051	1,594
Percentage from						
Branch	31·6	22·7	57·6	52·7	68·1	90·0
Upper trunk	38·6	42·1	27·1	35·7	25·9	9·2
Lower trunk	29·8	35·2	15·3	11·6	6·0	0·8
Percentage						
Mature	76·9	67·9	89·5	92·5	98·6	100·0
Immature	23·1	32·1	10·5	7·5	1·4	0·0
Percentage discarded ...	36·2	34·4	11·2	8·9	3·2	7·8
Percentage damaged by						
Black pod disease ...	32·0	40·3	15·8	11·9	2·6	1·8
Mealy ,, ,, ...	0·1	0·6	0·6	1·7	0·8	1·1
Brown ,, ,, ...	8·4	3·5	0·7	1·7	0·8	6·6
Warty ,, ,, ...	6·5	9·4	8·8	8·4	8·1	6·8
Helopeltis sp.	58·4	63·8	75·6	77·5	79·8	75·6
Other capsids	0·9	2·5	3·1	4·8	8·2	17·8
Rodents	9·1	3·6	1·5	3·3	2·3	9·3
Borers	19·1	12·7	14·7	18·5	22·9	31·8
Wt. of wet beans (lbs.) ...	228	299	860	642	441	312

Among minor points of interest may be noted also the following: the rise in percentage of pods discarded in December was occasioned by an increase in rodent and borer damage; the increase was even more marked in early 1950, as the off-season approached. The incidence of "brown pod disease" (*Botryodiplodia theobromae* Pat.) varied with the incidence of rodent damage—brown pod disease is a secondary condition incident largely upon damage from rodents and to a lesser extent, from borers and other insects. The branch crop assumed increasingly large proportions as the season progressed.

The complete results of the first year of the investigation are to be described elsewhere, as part of a general paper on pod diseases. The work should continue for several years, since environmental conditions vary considerably from season to season, with marked effect upon the incidence of pod diseases.

Calonectria rigidiuscula.

Inoculation experiments have been continued during the year to examine the behaviour of *C. rigidiuscula* in cacao and other plants. A second experiment to compare the invasive power of *C. rigidiuscula* with that of *Botryodiplodia theobromae* has been concluded but the results have not yet been analysed. The same applies to another experiment in which several introduced types of cacao (mainly Upper Amazon hybrids) were tested for possible resistance to *C. rigidiuscula* ; in this case, however, it is apparent without detailed analysis that these introduced types did not show any marked resistance to *C. rigidiuscula* compared with West African Amelonado cacao.

Inoculation into plants other than cacao.

C. rigidiuscula has been shown capable of acting as a wound parasite of a number of plant species other than cacao, by inoculating seedlings of these species with a spore suspension by the established technique. In each experiment ten plants of each species were employed, with two inoculations per plant, and ten cacao seedlings acted as controls. After eight weeks the seedlings were examined, the lesions measured in length and duplicate isolations made from the advancing edge of four lesions selected at random from the ten plants of each host species. In the first trial, the plant species were (in descending order of apparent susceptibility) *Cola cordifolia* R.Br., *Theobroma cacao* L. (control), *Bombax buonopozense* P. Beauv., *Triplochiton scleroxylon* K.Schum., *Ceiba pentandra* Gaertn., *Cola acuminata* Schott. & Engl., *Cola togoensis* Engl. & Krause, *Ptergota macrocarpa* K.Schum., *Desplatzia lutes* A. Chev., *Sterculia rhinopetala* K.Schum. and *Sterculia tragacantha* Lindl., all belonging to the closely related Bombacaceae, Sterculiaceae or Tiliaceae. The first two species appeared to be significantly slightly more susceptible than the last four (mean lesion lengths 7·9 and 5·7 mms. respectively). *C. rigidiuscula* of the same strain as that used for inoculation was recovered from the majority of lesions in the case of each host species.

In the second trial the species were representative of a more diverse selection of families, and there was a greater disparity in the size of the lesions than was observed in the first experiment. Lesion lengths in general were greater, the mean for *Theobroma cacao* in this experiment being 16·8 mms., compared with 7·9 mms. for the previous experiment ; seasonal variation appears to influence the progress of the fungus in the plant, and it has been noted previously that the results of one experiment cannot be compared with those from another experiment carried out at a different time.

C. rigidiuscula of the same strain as that used for inoculation was recovered from each host species except *Glyphaea lateriflora* and *Erythrina altissima*. Following are the plant species used, with the mean lesion length for each species. The first four appeared to be significantly more susceptible than average and the last two less susceptible (general mean lesion length 13·1 mms.).

TABLE 36.

Species.	Family.	Mean length of twenty lesions (mms.).
Celtis zenkeri Engl.	(Moraceae)	17·2
Milletia irvinei Hutch. & Dalz. ...	(Papilionaceae)	17·0
Theobroma cacao L. (control)	(Sterculiaceae)	16·9
Pseudospondias Microcarpa Engl. ...	(Anacardiaceae)	15·9
Picralima nitida Th. & Hel. Dur. ...	(Apocynaceae)	14·5
Khaya grandiflora C.DC.	(Meliaceae)	13·1
Conopharyngia sp.	(Apocynaceae)	12·4
Newbouldia laevis Seem.	(Bignoniaceae)	12·1
Glyphaea lateriflora Hutch. & Dalz. ...	(Tiliaceae)	10·8
Erythrina altissima A. Chev.	(Papilionaceae)	7·5
Spathodea campanulata Beauv. ...	(Bignoniaceae)	6·9

Isolations.

C. rigidiuscula has been isolated from occluded capsid lesions in cacao shoots collected in the British Cameroons, and has also been isolated at Tafo from lesions in shoots of *Aleurites triloba* Forst., the lesions being apparently due primarily to undetermined insect damage.

Biological Control of Mealybugs by Fungi.

The possibility of using fungi to control mealybugs has been partially investigated in laboratory experiments in collaboration with the Senior Entomologist and the Vector Entomologist. *Aspergillus* species of the *A. flavus-oryzea* group have been examined, and it is hoped to experiment at a future date with *Beauveria bassiana* (Bals.) Vuill.

Two strains of *Aspergillus parasiticus* Speare, NRRL 465 and NRRL 502 (ex type), hereinafter referred to as *A. parasiticus* (1) and (2) respectively, were received from the Northern Regional Research Laboratory of the United States Department of Agriculture at Peoria, Illinois, through the courtesy of Dr. K. B. Raper. In preliminary experiments these two strains were compared with a strain of *A. flavus* Link ex Fr. emend. wilh. isolated at Tafo as a saprophyte.

These early tests seemed to show that all three strains possessed some parasitic ability relative to mealybugs (*Pseudococcus njalensis* Laing), though *A. flavus* was much inferior in this respect to either strain of *A. parasiticus*. The spores were applied to the mealybugs by placing the latter in an actively sporulating plate-culture of the fungus and gently rolling the insects over with a brush.

In succeeding experiments the conditions were more nearly those of field practicability, the spores being applied diluted with talc dust, in a

dust tower. Two control treatments involving no fungus spores were employed, one in which talc dust alone was applied to the mealybugs, the other consisting of no dust application at all. Since in the earlier trials *A. flavus* appeared to show some degree of parasitic ability itself, one treatment employed a species of *Aspergillus* not related to the *A. flavus* series, namely *A. niger* van Tiegh. *sens. strict.* The remaining two out of the six treatments included in these experiments employed strains (1) and (2) of *A. parasiticus.*

Each treatment involved the application of 0·25 gm. of talc dust, containing (in treatments 3 to 6) approximately 12,000 fungus spores, to 100 adult mealybugs divided into four batches of 25, each batch being contained in a Petri dish of diameter 7·5 cms. The four Petri dishes stood on the floor of the dust tower, of diameter 25 cms. The dust was blown upwards into the tower at a pressure of 20 lbs. per sq. in. and allowed three minutes to settle. Each Petri dish contained a filter paper moistened with sterile water.

The plates were examined under a binocular microscope after 48, 72, 96 and 120 hours. The summary in the Table below of the numbers of mealybugs dead after these intervals in the first experiment using talc-dispersed spores shows that under the conditions of this experiment *A. parasiticus* could effectively parasitise *P. njalensis. A. flavus* and *A. niger* appeared to have a slightly deleterious action ; most of the bugs which died under those treatments had fructifications of the respective *Aspergillus* sp. growing out of the corpses. The increase in death rate among the controls after 120 hours was due to the accidental contamination of those plates by an *Aspergillus* spp. of the flavus group. probably one of the strains of *A. parasiticus.*

TABLE 37.

Treatment.	Total number (= %) of bugs dead after the following intervals.			
	48 hrs.	72 hrs.	96 hrs.	120 hrs.
1. Control : no treatment ...	1	1	1	3
2. Control : talc alone	0	0	0	4
3. *Aspergillus niger*	1	3	3	5
4. ,, *flavus*	3	5	8	11
5. ,, *parasiticus* (1) ...	1	23	96	98
6. ,, *parasiticus* (2) ...	2	13	90	95

The above experiment was repeated, using the same dusts after they had been stored for ten weeks in corked tubes. The corrected percentage deaths after 96 hours for the fresh dust and for the dusts which had been stored for ten weeks are given in Table 38, and it will be seen that the results are closely comparable.

TABLE 38.

CORRECTED PERCENTAGE DEATHS AFTER 96 HOURS.

	Fresh dust.	Dust stored 10 weeks.
No treatment	0	0
Talc alone	−1	0
A. niger	2	6
A. flavus	7	20
A. parasiticus (1)	96	97
A. parasiticus (2)	90	97

VIII. MEALYBUG STUDIES.

Biological Control.

Laboratory Rearing of Mealybugs.

1. *Host Plants.*

The following plants have been employed as hosts for rearing mealybugs on which to breed parasites.

(*a*) *Potatoes :* These have proved more suitable than any other plant tested, but results have not been consistently good due to considerable variation in the quality of the potatoes available and to the frequent occurrence of moulds and bacteria which cause the tubers and sprouts to rot. Imported potatoes, though more susceptible to rotting than locally grown tubers, produce stronger and more succulent sprouts. Ordinary laboratory and insectary temperatures appear to be too high and the most satisfactory results have been obtained in relatively cool, dark rooms in which the temperature varies from 77° F. to 81° F.

(*b*) *Chinese Yams* (*Dioscorea esculenta* var.) : Sprouts readily develop in the laboratory and the tubers are much less susceptible to rotting than are potatoes. Mealybugs, particularly *Pseudococcus citri*, are readily established on the young sprouts but do not increase in number to the same extent as on potato sprouts.

(*c*) *Spineless cactus :* (*Nopalea* sp.) : This plant has kept well in the laboratory but mealybugs have not established satisfactorily on it.

Other plants tested, which did not give a suitable type of growth for laboratory rearing of mealybugs included cacao, cocoyam (*Colocasia* sp.) and beans (*Phaseolus* spp. and *Glycine hispida*).

2. *Mealybugs.*

P. citri can be reared in the laboratory more readily than *P. njalensis* and will be used as the host for the mass breeding of parasites when supplies of apparatus have been received. A small culture of *P. njalensis* will be maintained on which to test new introduced parasites for ability to breed on this host.

The Introduction of Parasites and Predators.

1. *Parasites.*

(*a*) *Anagyrus kivuensis* Compere was introduced into the Gold Coast from Kenya in 1948 before any parasite-free stocks of mealybugs were available and it was therefore reared on *P. njalensis* collected in the field. This resulted in serious contamination of the culture with indigenous species of parasites including a species of *Anagyrus* near *A. pullus* Compere which cannot be distinguished in the living state from *A. kivuensis.* Rearing has therefore been discontinued until suitable mealybug cultures are available, when this promising species will be reintroduced from Kenya.

(*b*) Specimens of *Leptomastix dactylopii* Howard were sent from California by the Commonwealth Bureau of Biological Control during December, 1949, as pupae and adults. The 2,000 adults all died during transit but from approximately 21,000 pupae a good emergence was obtained. The adults however did not live for long, about two-thirds of them dying during the first 48 hours. 925 were retained for breeding purposes and the remainder were liberated at five places in the Eastern Province of the Gold Coast.

Of those kept in the insectary none lived for more than five days and emergence of adults in the next generation, using *P. citri* as a host, was very poor, only 46 being obtained. The parasites failed to reproduce on *P. njalensis* and the culture died out after the third generation on *P. citri.*

Over 14,000 *P. njalensis* adults and final instar nymphs and 400 specimens of other species of *Pseudococcus* have been collected from the areas in which releases were made and set up for the emergence of parasites. No *L. dactylopii* have been recovered during the three months which have elapsed since the release of the parasites.

2. *Predators.*

About 35,000 adult Coccinellidae (Ladybird beetles) were received from California in September, 1949, and released in four localities in the Eastern Province of the Gold Coast. These belonged to five species, *viz.*, *Scymnus binaevatus*, *S. quadrivittatus*, *Chilocorus angolensis*, *Exochomus flavipes* and *Nephus* sp. Except for a few individuals of each of the last two species mentioned above which were collected within a week of the original release date no recoveries have been made yet from any of the areas.

Indigenous Parasites and Predators on Mealybugs.

Collections of the natural enemies have been made from numerous localities throughout the Gold Coast cacao belt and over thirty species have now been reared from mealybug vectors of swollen shoot virus. These include Lepidoptera, Coleoptera, Diptera, Neuroptera, Hymenoptera and one mite. Many are known to be primary parasites or predators on the mealybugs, a few are hyperparasites or parasites of predators and the function of others is as yet unknown. Many have not yet been named and have been sent to the Commonwealth Institute of Entomology and to private workers for examination, and a fuller report on these will be made when determinations have been received.

Chemical Control.

Through the courtesy of Dr. B. A. Kirby of the University of Leeds and Dr. R. A. E. Galley of the Agricultural Research Council, samples of two chemicals which appear to show systemic properties (*i.e.*, they can be taken up into the plant system and translocated throughout the plant) were obtained.

The two chemicals, bis (bis dimethylamino) phosphonous anhydride and bis (dimethylamino) fluoro phosphine oxide, will be referred to as BBPA and BFPO respectively throughout this report.

These chemicals were added to an NPK nutrient solution so that the final concentrations were 10, 50 and 100 parts per million (Experiment A). Later, concentrations of 200 and 500 p.p.m. (Experiment B) were used. Young, vigorous cacao seedlings were transferred to the solutions and observed at regular intervals. In Experiment A the plants continued to grow satisfactorily and no set-back was observed with either chemical, but in experiment B phytotoxic action was apparent in a very short time with both 200 and 500 p.p.m. of BFPO.

Seedlings growing in plain solution were kept as controls.

Three different species of mealybug were used :—

1. *P. citri* natural infestation of established colonies.

2. *P. njalensis* artificial infestation by 10 adult female mealybugs per plant. Establishment varied but some mealybugs settled down in every case.

3. *F. virgata* artificial infestation by 5 adult female mealybugs per plant.

Results.

Experiment A.

With BBPA all species of mealybug settled down well at 10 p.p.m. and 50 p.p.m. and at the end of eight weeks flourishing colonies of adult mealybugs and crawlers were found on all the plants. At 100 p.p.m. the development of the colonies was retarded but after eight weeks all of the trees used still had small surviving colonies.

With BFPO all the plants were entirely free from mealybugs at the end of four weeks except in the case of one, infested by *F. virgata* at 100 p.p.m., on which a very small colony persisted into the fifth week.

Experiment B.

At both 200 p.p.m. and 500 p.p.m. BBPA caused a reduction in the number of *P. citri*, the only species used in this experiment, but at the end of eight weeks adults and crawlers were present on nine out of ten plants at 200 p.p.m. and on six out of ten plants at 500 p.p.m.

BFPO showed a well defined phytotoxicity at 500 p.p.m. and at the end of the experimental eight weeks none of the plants survived. At 200 p.p.m. the toxic effect on the plants was not so severe but even so, four out of ten died and one or two others were badly affected. Because of this no results of any value were obtained at these concentrations with this chemical.

IX. ARBORICIDES.

Chemical Destruction of Alternative Hosts of Cacao Viruses.

During the month of June, 1949, experiments were commenced with chemical arboricides to determine if their use under local conditions was practicable for destruction of forest trees known to be alternative hosts of cacao viruses.

The species whose destruction by means of arboricides is considered desirable include *Ceiba pentandra* and *Cola cordifolia*. These trees may reach huge dimensions ; when they are felled, the crown causes extensive damage to surrounding cacao. If, however, they are killed whilst still standing, the crown disintegrates gradually and the falling pieces cause comparatively little damage to the cacao underneath. The experiments in question, which are of a preliminary nature only, made use of four arboricidal substances :—

1. Sodium Arsenite	25 per cent. aqueous solution.
2. Copper Sulphate	25 per cent. aqueous solution.
3. Sodium salt of 2,4-dichlorophenoxy acetic acid ...	3 per cent. aqueous solution + 1 per cent. wetting agent.
4. Isopropyl ester of 2,4-dichlorophenoxy acetic acid ...	3 per cent. aqueous emulsion.

Four trees of each species were selected for treatment with each poison. Two of each species were treated in the morning (9.00–11.00 hr.) and two in the afternoon (16.15–18.15 hr.). All trees were girdled about three feet above ground level and the poison was poured into the cut.

A summary of the results obtained is included in the appended Table.

As a result of these preliminary experiments, the use of sodium arsenite has been adopted as a routine measure on the station for the removal of redundant trees. For this purpose the sodium arsenite is obtained as a strongly alkaline, concentrated solution and is diluted to ten per cent. with starch paste. The viscous mass so obtained does not run out of the girdle cut in the tree as does an ordinary solution.

TABLE 39.

Tree No.	Species.	Girth Ft.	Girth In.	Poison used.	Concentration (% w w).	Quantity used (c.c.).	Time of application.	Condition ten months after treatment.
7	Ceiba	4	5	Sodium Arsenite	25	200	Morning	Dead
21	,,	4	10	,, ,,	25	250	,,	,,
39	,,	2	7	,, ,,	25	50	Afternoon	,,
40	,,	3	3	,, ,,	25	50	,,	,,
18	Cola	7	8	,, ,,	25	350	Morning	,,
19	,,	6	0	,, ,,	25	400	,,	,,
44	,,	7	5	,, ,,	25	300	Afternoon	,,
45	,,	5	5	,, ,,	25	250	,,	,,
12	Ceiba	8	0	Copper sulphate	25	300	Morning	Alive
20	,,	2	4	,, ,,	25	150	,,	,,
41	,,	2	6	,, ,,	25	50	Afternoon	Dying
42	,,	1	9	,, ,,	25	50	,,	Alive
14	Cola	6	8	,, ,,	25	350	Morning	,,
16	,,	13	8	,, ,,	25	750	,,	,,
43	,,	7	2	,, ,,	25	250	Afternoon	,,
46	,,	7	1	,, ,,	25	300	,,	,,
2	Ceiba	1	5	Sod. salt of 2,4-D.	3	90	Morning	Dead
6	,,	12	0	,, ,,	3	650	,,	Alive
27	,,	1	7	,, ,,	3	50	Afternoon	Blown down
30	,,	2	1	,, ,,	3	50	,,	Alive
8	Cola	7	9	,, ,,	3	400	Morning	,,
17	,,	8	0	,, ,,	3	400	,,	,,
28	,,	4	5	,, ,,	3	100	Afternoon	,,
4	Ceiba	3	8	Isopropyl Ester of 2,4-D.	3	180	Morning	Alive
22	,,	9	0	,, ,,	3	400	,,	,,
31	,,	5	4	,, ,,	3	200	Afternoon	,,
33	,,	4	11	,, ,,	3	200	,,	,,
3	Cola	7	5	,, ,,	3	200	Morning	,,
5	,,	7	0	,, ,,	3	400	,,	Felled
36	,,	6	4	,, ,,	3	300	Afternoon	Alive
37	,,	9	1	,, ,,	3	350	,,	,,

X. AGRONOMY.

Sub-stations.

Climatic conditions have been more favourable for the establishment and growth of cacao than in previous years, and the young trees have formed a full canopy on most areas where the conditions are suitable for cacao growing.

Further replanting has been abandoned on those sections of all the farms where it is obvious that, due to soil or moisture conditions, cacao will not thrive. These areas fall into two main groups, namely those where only a shallow soil is overlying the rocks and those low-lying sandy areas where a high water table confines the root system of the cacao seedlings to the upper stratum and, on recession in the dry season, leaves them without an adequate supply of soil moisture.

Capsid control, using D.D.T. emulsion applied by hand, has continued to give highly satisfactory protection, but much of the more forward cacao is getting too tall for this method to be employed successfully.

Drought effect was most severe on those areas mentioned in the second paragraph, particularly at Akwadum and Kukua. The earlier maturity of the cacao on the drier farms as indicated by pod yields is noteworthy.

Akwadum.

Growth was good until early February when 755 trees (10 per cent. of the original stand) were lost through drought in one area of three acres sited on sandy soil; most of the surviving trees, although completely defoliated, have flushed and made a complete recovery.

Heavy pruning of damaged branches was necessary in October after a rapid increase in capsid population, hand painting having proved ineffective on the larger trees. Treatment with 10 per cent. D.D.T. dust proved equally disappointing owing to the vagaries of the weather, heavy rain almost invariably following the applications.

Machine spraying in December reduced the capsid population to negligible numbers.

Swollen shoot symptoms were found on 11 trees, all of which were near the edge of the farm; these trees were removed.

Routine operations included the thinning of the cacao on the "native randomised" plots to a density of around 800 to the acre.

1,731 pods were harvested during the year.

Nankese.

Except for defoliation during the December dry spell the cacao has continued to grow well throughout the year.

No swollen shoot infection was found and capsid damage has remained at a low level.

The cacao on the good areas has now formed a complete canopy and the trees are flowering heavily.

Thinning of the stand has been effected where necessary.

238 pods were harvested during the year.

Upper Amazon type seedlings have become established on two of the areas where Amelonado failed in four successive years, but it is only fair to point out that the dry season was much less severe than usual.

Kukua.

Heavy defoliation during the dry period December to February was followed by almost complete recovery with the advent of the rains.

The growth of the cacao in, and on the slopes of the valleys was excellent, and 1,202 pods were harvested, mainly from these areas.

Capsid incidence and damage were somewhat more severe than in previous years on the unpainted plot and for the first time the efficacy of D.D.T. painting was demonstrable.

During the year 15 seedlings were discovered with swollen shoot disease, 14 of these being on Plot A in close contact with diseased seedlings which had been left for observation and with infective material on neighbouring land.

Most of the diseased trees in farms contiguous to Plots B and C have been removed during food farming operations and the single diseased seedling on this section of the farm emphasizes the value of isolating new plantings.

Cacao seedlings growing under or in proximity to oil palms appeared to be tolerant to drought.

Adonkwanta.

On this sub-station, where the rainfall is heavier than on the other four, the effect of the drought was negligible.

There were 13 infected seedlings found during the year, six on the treated Plot B and seven on Plot A, all being near the border of the farm.

Capsid damage was again severe on the untreated half of the farm, whilst the cacao on the other half remained almost free from damage.

Shade trees on both plots were thinned out, the regeneration of indigenous trees on this farm being particularly good.

The population of cacao seedlings on the better areas of Plot B was reduced by the removal of the weaker plants ; on the greater part of Plot A capsid damage has reduced the stand to less than the optimum.

There were no pods harvested during the year but there is heavy flowering for the next crop on the more advanced parts of the farm.

Koransang.

The growth of the young cacao on this farm has been excellent, except on the rocky portions, where further replanting would appear fruitless.

Losses from swollen shoot disease were lower than last year, being 218 mature trees, 12 seedlings and 10 coppiced trees.

Flowering is general on the seedlings planted in 1945–46.

Capsid damage was very slight, incipient pockets being painted as soon as they became evident.

The reduction of shade by ring barking the *Gmelina arborea* trees has proved very beneficial to the cacao.

Meteorology.

Monthly and Annual Rainfall in inches are tabulated in Appendix I.

TAFO STATION.

A. Cacao Crop.

1. *Old Station.*

The light crop harvest, which began at the end of May, merged into the main crop at the end of August.

Following an abnormally wet June and July, there was a rapid increase in the amount of Black Pod disease. More frequent harvesting was adopted and the interval between pickings was reduced to one week.

During the crop season a total of 29 pickings was made, all operations being carried out by one gang of labourers, who spent three and a half days picking and recording the crop and the remainder of the week breaking pods and fermenting the beans.

The effect of this measure is reflected in Table 40, there being a spectacular fall in the percentage of pods discarded.

One other important consequence of this method of harvesting was a saving in labour costs of nine man days per acre (approximately 20 per cent.) for the main crop compared with those of the previous crop season.

TABLE 40.

DELIVERY OF CROP FROM 63·69 ACRES.

(*a*) Light Crop.

Date of picking.	Total pods harvested.	Per cent. pods discards.	Wet weight beans lb.	Per cent. dry to wet.	Pods per lb. dry.
1949					
May 31–June 10	8,390	13·5	1,125·9	35·5	15·5
July 4–12 ...	8,987	6·1	1,803·7	33·0	12·0
,, 25–Aug. 4 ...	13,133	29·3	1,950·6	34·4	11·3
Aug. 15–20 ...	21,734	32·3	3,984·9	32·1	11·1
,, 22–25 ...	15,866	21·7	3,171·9	35·8	10·4
,, 29–31 ...	18,443	10·8	4,260·2	37·3	9·9
Total	86,553	20·8	16,297·2	34·8	11·1

(*b*) Main Crop.

Sept. 5–8 ...	27,861	5·4	6,569·6	39·22	9·8
,, 12–14 ...	20,726	5·0	5,164·2	36·80	10·0
,, 19–21 ...	31,173	3·7	7,310·8	37·04	10·1
,, 26–30 ...	27,317	5·8	6,401·3	37·55	10·3
Oct. 3–5 ...	20,837	7·2	4,467·9	39·92	10·5
,, 10–12 ...	19,223	6·1	4,033·0	38·11	11·3
,, 17–19 ...	15,819	4·6	3,393·6	37·75	11·3
,, 24–26 ...	24,058	3·2	5,291·8	41·93	10·3
,, 31–Nov. 2 ...	34,253	2·1	7,272·8	40·59	11·1
Nov. 8–10 ...	32,427	2·3	6,710·1	39·94	11·6
,, 15–17 ...	22,360	2·5	4,494·1	41·91	11·3
,, 21–24 ...	15,636	4·6	2,994·8	40·16	12·1
,, 28–30 ...	12,155	4·7	2,276·9	40·84	12·1
Dec. 5–7 ...	15,061	4·0	2,911·2	41·38	11·7
,, 12–14 ...	14,128	2·8	2,691·4	38·55	12·9
,, 19–21 ...	11,265	3·1	2,089·1	38·55	13·1
,, 28–29 ...	9,319	3·4	1,799·1	38·45	12·6
1950					
Jan. 3–5 ...	4,936	5·5	845·9	38·45	13·5
,, 9–11 ...	2,436	6·8	392·4	43·31	12·3
,, 16–18 ...	1,661	6·4	264·9	38·60	13·8
,, 23–25 ...	950	9·2	138·4	38·19	14·2
,, 30–Feb. 1 ...	559	8·9	88·5	34·08	14·4
Feb. 6–8 ...	373	11·3	58·2	36·12	14·1
Total	364,535	4·2	77,660·0	39·27	11·1
Grand Total ...	451,088	7·4	93,957·2	38·50	11·1

All cacao produced was of first grade quality.

The total yield from all recorded plots was 13 per cent. less than that for the same area last year and 13·3 per cent. less than the 12-year mean.

TABLE 41.

LIGHT/MAIN CROP SEASONS.

Figures for 1949–50 compared with 12-year means (63.6875 ac.).

Period.	Total pods harvested.	Per cent. pods discards.	Wet weight beans lb.	Per cent. dry to wet.	Yield per acre in lb. dry.
Light					
12-Year Mean...	62,431	17·7	11,706·2	37·58	65·5
1949–50 ...	86,553	20·8	16,297·2	34·80	89·0
Main					
12-Year Mean...	523,825	12·6	94,043·9	41·82	589·2
1949–50 ...	364,535	4·2	77,660·0	39·27	478·9
Light/Main					
12-Year Mean...	586,257	13·1	105,750·3	41·35	654·7
1949–50 ...	451,088	7·4	93,957·2	38·50	567·9

An analysis of the Distribution of Yields on 224 one quarter acre plots of the Uniformity Trial Area is given in Table 42.

TABLE 42.

DISTRIBUTION OF PLOT YIELDS FROM 224 × ¼-ACRE PLOTS.

Yield classes.	Percentage of total number of plots in each class.				
	1945/46	1946/47	1947/48	1948/49	1949/50
0– 200	8·5	16·5	13·4	5·36	5·80
201– 400	25·3	34·8	38·0	13·84	20·09
401– 600	35·1	26·8	36·2	24·11	30·36
601– 800	19·1	15·6	8·9	24·55	25·00
801–1,000	8·0	4·9	3·1	18·30	16·07
1,001–1,200	3·6	0·9	0·4	8·93	2·23
1,201–1,400	0·4	—	—	4·46	0·45
1,401–1,600	—	0·5	—	0·45	—
1,601–1,800	—	—	—	—	—
Highest plot yield in lbs. per acre	1,251·60	1,527·60	1,051·48	1,485·60	1,252·84
Lowest plot yield in lbs. per acre	2·92	Nil	Nil	3·68	1·64

The modal class has fallen from 601–801 lbs. per acre in the previous season to 401–601 lbs. per acre in the season under review.

Warty pods.

There would appear to be a reduction in the incidence of Warty Pods since last season as is indicated in Table 43.

TABLE 43.

Picking.	Total pods.		Per cent. Discards.	Total warty pods.		Warty pods.		Healthy pods.	
	(1) Harvested.	(2) Discarded		Harvested.	As % of (1).	Discarded.	As % of (1).	With warts.	As % of (1).
Light 48/49 ...	56,417	3,049	5·4	5,060	9·0	672	1·2	4,388	7·8
Light 49/50 ...	86,553	17,998	20·8	3,703	4·3	16	0·02	3,687	4·3
Main 48/49 ...	431,896	23,884	5·5	32,389	7·5	6,057	1·4	26,332	6·3
Main 49/50 ...	364,535	15,173	4·2	10,923	3·0	2,076	0·6	8,847	2·4
Total 48/49 ...	488,313	26,933	5·5	37,449	7·7	6,739	1·4	30,720	6·3
Total 49/50 ...	451,088	33,171	7·4	14,626	3·2	2,092	0·5	12,534	2·8

Tree Mortality.

There was a reduction from the previous year in the number of trees lost from swollen shoot disease and other causes. Of the 625 mature trees lost, 354 were infected with swollen shoot disease, 33 were suspected of suffering from the same, and 238 died from other causes.

Forty seedlings were lost owing to swollen shoot disease from an estimated population of 75,000, this being a marked increase on the previous year's figure of nine.

2. *Square Mile.*

More frequent harvesting was practised as on the Old Station and a reduction in losses from pod diseases was effected.

B. Field Experiments.

Growth on all experimental areas has been satisfactory but experience has shown that sudden reduction of shade is undesirable. This conclusion was reached when, owing to the top-heavy growth produced in the third year, Tree Cassava was removed " in toto " from the Uniformity and Establishment Trials planted in 1947.

The immediate response of the cacao seedlings was the production of a heavy flush, but this was followed by a heavy infestation of thrips, with a consequent reduction in effective leaf surface.

With our present methods, there is a period in the third and fourth year of establishment of young cacao, under conditions where no overhead shade existed at the time of planting, when the Tree Cassava and Bananas have outlived their usefulness as components of the " Salad Shade " and the Gliricidia and the indigenous tree seedlings are not sufficiently

advanced to provide adequate shade on their own. Numerous indigenous trees have been tried in an attempt to fill this gap, both as seedlings and " stake " cuttings, so far without success. The indigenous pioneer species *Trema guineensis* provides an ideal type of shade but unfortunately all seed collected to date has had a very low viability.

Protection against capsids has been provided by continued painting with D.D.T. emulsion.

The Uniformity Trial.

A census of seedlings in this experiment showed that 43·78 per cent. of the seedlings had reached the " jorquette " stage at the end of the year, with an average height throughout of 4 ft. 6 in. A few of the most advanced seedlings have started to flower.

The First Establishment Trial.

Forest tree regeneration has been particularly good on this area.

Growth of the cacao has been good throughout, but the treatment using basket seedlings continues to be outstanding.

Deaths in all plots amounted to only 33, fairly evenly distributed amongst the treatments.

The Spacing Trial.

The Gliricidia, which had been used to augment the shade after thinning the banana hedges, has made good progress. All banana stools have been maintained at three stems per stool.

Only 17 seedlings out of a population of 20,958 were lost during the year.

There is no real difference in the growth of individual seedlings in the various treatments, although the denser vegetation of the closer spacings gives the impression of better establishment.

The Thinning Trial.

A similar impression of relatively better growth on the closely spaced treatments, as appears in the Spacing Trial, has no foundation in fact.

The seedlings on the 2 ft. × 2 ft. planted plots are somewhat taller on the average than those on the plots planted at 8 ft. × 8 ft. but are much more etiolated.

Early Seed Production Experiment.

Despite the removal of flowers to prevent cropping during the 1949–50 main crop season, the treated trees showed no sign, at the end of March, of producing a greater number of pods than the untreated ones which had produced a main crop.

The Upper Amazon Type Spacing Trial.

This experiment, laid down in the current year, was planted in June. The object of the experiment is to ascertain the optimum spacing at which to plant the vigorous progenies of the Upper Amazon Types of cacao introduced from Trinidad in 1944. The original introductions were

planted at 14 ft. × 14 ft. and it was considered that spacings of 8 ft. × 8 ft., 10 ft. × 10 ft. and 12 ft. × 12 ft. would provide an effective range for investigation.

The layout provides for these three treatments, randomised within the blocks and replicated five times.

The five acre experimental area extends across a valley and all types of soil which occur on the Institute's land are represented.

Planting material consisted of six month old basket seedlings of selections T.12, T.60, T.63, T.85 and T.87. Selections T.12, T.60 and T.63 each occupy a replication of the spacing treatments. T.85 and T.87, the parents of which are from reciprocal crosses, occupy a fourth replication, whilst the fifth replication contains all selections planted in randomised double rows, to ensure freer cross pollination.

Tree Cassava and Gliricidia are employed as nurse shade plants, whilst the overhead canopy has been left untouched.

It is proposed to prune half of each treatment plot, limiting growth to one tier of " jorquette " material with the object of comparing pruned and unpruned cacao of this type at the various spacings.

The tolerance of the seedlings to varying conditions (including water-logging in the valley bottom for a period of three weeks) has been remarkable.

Many of the seedlings had produced " jorquette " branches at 12 months from seed, and the lush growth has made it necessary to use prophylactic D.D.T. as a protection against capsids at a much earlier age than would be necessary with West African Amelonado cacao.

An additional five acres, using younger material of the same selections, was planted in October, with the object of producing seed of the selections for eventual issue to the Nigerian Agricultural Department ; the treatment plots were carried through on the same layout.

The seedlings were planted in traverses cut through the existing bush which has been since thinned, to admit light to the seedlings and nurse shade plants.

Growth has been excellent.

The Second Establishment Experiment.

This experiment, designed to compare three methods of establishing West African Amelonado Cacao and the effects of the resultant shade on the mature trees, was planted in June.

The layout consists of three treatments, each replicated three times in randomised blocks.

Spacing is at 8 ft. × 8 ft., using three seeds per stand.

The treatments are as follows :—

(i) Initial shade consists of tree cassava planted at 8 ft. × 8 ft., all undesirable bush having been removed, leaving indigenous tree seedlings. The final shade is to consist of forest trees.

TABLE 44.

Month.	New outbreaks.	Trees destroyed.		Classification of trees removed.		Total.
		New outbreaks.	Old outbreaks.	Swollen shoot infection.	Suspects.	
1949						
April ...	5	14	40	50	4	54
May ...	3	10	30	37	3	40
June ...	3	7	40	42	5	47
July ...	2	4	50	52	2	54
August ...	1	2	18	17	3	20
September ...	3	7	11	18	—	18
October ...	5	7	19	21	5	26
November ...	2	4	27	28	3	31
December ...	1	3	9	10	2	12
1950						
January ...	1	1	8	9	—	9
February ...	8	19	32	46	5	51
March ...	7	10	15	24	1	25
1949–50 ...	41	88	299	354	33	387
1948–49 ...	60	134	385	495	24	519

40 infected seedlings were removed during the year.

TABLE 45.

TREES DESTROYED DURING TREATMENT—SQUARE MILE 1949–50. EXCLUDING BLOCK "A".

Month.	Diseased.	Suspects.	Contacts.	Total.
1949				
April	420	27	270	717
May	177	19	120	316
June	423	7	94	524
July	244	7	134	385
August	171	8	84	263
September	375	26	137	538
October	86	15	87	188
November	51	14	65	130
December	265	45	116	426
1950				
January	105	13	50	168
February	154	18	68	240
March	115	9	41	165
Total	2,586	208	1,266	4,060
Total 1948–49	7,486	875	3,489	11,850

(ii) Cacao planted in 3 ft. wide traverses, cut through the secondary bush, with Gliricidia planted at 8 ft. × 8 ft. The bush is intended to provide the shade in the early years, the final shade being a pure stand of Gliricidia.

Cacao in this treatment is to be pruned back to one tier of fan branches. (Low shade over low cacao.)

(iii) Method of planting is as in Treatment (ii) with no supplementary shade. The final shade is to consist of forest trees, which will be fostered during the early years.

During the period under review the growth of the seedlings has been good, with slightly better growth in the more lightly shaded Treatment (i).

The removal of creepers and undesirable " bush " in the other treatments after the early rains, resulted in a rapid flush response. A further replication of the same treatments, using Upper Amazon Type cacao, was planted in February as a demonstration plot.

Clonal Plots.

Routine maintenance and capsid control measures were conducted on the Clonal Multiplication Plots of the Pathology Division.

Herrania Multiplication Plot.

Growth of the Herrania seedlings has been excellent ; the average height after 14 months in the field is 3 ft. 6 in.

Routine Planting.

Growth on all plantings has been good and routine shade control has been effective.

A further four and a half acres of West African Amelonado cacao for use as experimental material was planted during the year.

Swollen Shoot Control.

The eradication of swollen shoot disease from cacao on the Institute's lands was continued.

The policy of removing trees, suspected of carrying virus but not showing symptoms, appears to have attained a large measure of success in retarding the spread of the disease.

The number of new outbreaks and infected trees in the Old Station has declined since this policy was adopted in October, 1948, and on the Square Mile the spectacular drop in infection, whilst partially accounted for by the final infection and eradication of narrow tongues of trees between initial outbreaks, is probably mainly due to the removal of suspected infective material outside the actual contact areas.

Table 44 is a summary of the swollen shoot treatment figures on the Old Station and Table 45 records the " cutting-out " data for that section of the Square Mile reported upon in the previous annual report.

On Block A of the Square Mile, where no re-treatment had been carried out since 1945, a second treatment in September, 1949, involved the removal of 4,847 infected and contact trees and subsequent re-treatment accounted for a further 12.

This area had been allocated to the Pathology Division for observation and experimentation in the interim.

The incidence of swollen shoot disease on young cacao in the sub-station and the Old Station is shown in Table 46.

The total number of plants is as shown in the 1948–49 report, but some of the more forward areas have been thinned during the year with a consequent reduction in seedling population.

TABLE 46.

Station.	Date planted.	Approx. Seedling Population.	Diseased plants.							Total.
			1943-44	1944-45	1945-46	1946-47	1947-48	1948-49	1949-50	
Akwadum...	1942	28,000	1	2	2	2	47	17	11	82
Koransang	1945	15,000	—	—	3	31	72	20	12	138
Kukua ...	1945	50,000	—	—	—	1	23	30	15	69
Nankese ...	1945	35,000	—	—	—	1	2	1	—	4
Adonkwanta	1945	56,000	—	—	—	12	60	17	13	102
Tafo (Old Station)...	1940–1948	90,000	—	—	—	1	2	5	40	48

Tafo Station : Maintenance and General.

Cacao.

Young seedling cacao was thinned twice during the year, care being taken to maintain, as far as possible, a close canopy. The thinning operation was found to be most effective in this respect if carried out immediately before a flushing period. Capsid control measures, using D.D.T. emulsion, were undertaken after thinning.

Basal chupons on mature trees were restricted to not more than two per tree, and only those arising at less than 4 in. from the base were retained.

Large numbers of indigenous tree seedlings have been raised in nurseries and transferred to baskets for planting in the mature cacao areas, since only 20 per cent. of those planted directly from the nursery beds in the previous season had survived. The naturally regenerated tree seedlings have been protected during routine brushing operations.

Nurseries.

During the year under review, 16,212 seedlings of Upper Amazon Type cacao were issued or used on experimental areas, a stock of 13,130 remaining at the end of the year.

General.

Routine maintenance of roads, buildings and compounds continued.

Seven wells, lined with concrete rings, were sunk in the W.A.C.R.I. Village area to provide water for the occupants until such time as the piped water supply is available.

Ten acres of land unsuited to cacao were planted with miscellaneous food crops.

Four thousand five hundred pounds of vegetables were produced.

Anti-malarial measures continued and the mosquito population remained at a low level. The practice of burying all cacao husks during harvest was discontinued. Pods are now quartered, to prevent accumulation of rain water for possible mosquito breeding sites, and are spread as a mulch under the cacao.

APPENDIX I.

METEOROLOGICAL DATA.

FIGURES FOR 1949 COMPARED WITH 12-YEAR MEAN.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Highest Shade Maximum 12-year mean	91·3	93·4	93·4	93·1	92·0	89·3	86·8	86·3	87·9	90·0	90·4	90·4
„ „ „ 1949... ...	93	95	94	94	93	92	88	87	88	93	92	91
Lowest Shade Maximum 12-year mean	58·6	61·8	65·9	65·9	66·8	66·8	66·6	65·4	67·3	66·5	65·1	62·3
„ „ „ 1949	57	62	67	67	68	67	67	68	69	64	67	66
Mean Relative Humidity 12-year mean (9 a.m. G.M.T.)	85·8	83·9	81·6	81·0	81·7	84·5	85·7	85·7	84·6	82·6	81·4	83·7
Mean Relative Humidity 1949	88·2	85·6	84·5	81·4	82·5	85·2	87·4	86·4	86·9	82·5	83·0	85·6
Mean Relative Humidity 12-year mean (15.00 G.M.T.)	52·7	50·4	53·0	55·9	60·8	66·5	67·6	57·8	70·6	69·2	65·1	60·9
Mean Relative Humidity 1949	58·5	53·9	62·1	59·1	65·3	71·9	76·0	74·9	74·7	69·7	66·9	58·6
Rainfall in inches 12-year mean ...	1·24	3·52	5·76	5·90	7·22	8·59	5·63	2·98	5·95	7·84	5·45	2·70
„ „ „ 1949	0·61	3·46	7·15	4·79	5·87	9·12	14·73	4·37	8·84	3·63	3·52	5·72
Number of wet days 12-year mean ...	3·5	7·5	12·0	11·2	13·8	18·9	13·4	13·5	17·8	17·2	11·4	6·5
„ „ „ 1949	1	6	15	13	16	23	20	16	22	14	11	4

ANNUAL RAINFALL FIGURES: 1938–49.

1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	12-year Mean.
55·33	84·96	56·92	56·59	59·45	69·09	49·12	68·87	47·03	67·30	66·99	71·81	62·78

MONTHLY RAINFALL (IN INCHES) AND NUMBER OF WET DAYS—JANUARY 1949–MARCH 1950.

	1949 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1950 Jan.	Feb.	Mar.
Rainfall in inches	0·61	3·46	7·15	4·79	5·87	9·12	14·73	4·37	8·84	3·63	3·52	5·72	6·24	5·22	7·36
Number of wet days ...	1	6	15	13	16	23	20	16	22	14	11	4	4	3	10

MONTHLY RAINFALL IN INCHES FOR THE YEAR 1949.

Station.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov	Dec.	Total.
Akwadum ...	0·9	1·75	8·74	2·07	4·71	7·84	10·74	3·6	8·04	3·13	3·13	1·33	56·01
Nankese ...	0·28	1·93	9·45	2·95	5·99	8·79	10·26	3·65	8·59	3·09	2·16	0·48	57·62
Koransang ...	1·0	1·79	9·09	4·54	4·53	9·23	11·34	4·52	11·44	3·41	8·83	0·32	70·04
Kukua ...	0·79	1·77	8·40	2·57	6·3	12·21	11·31	4·96	12·68	3·1	6·16	0·19	70·46
Adonkwanta...	1·17	3·2	6·51	6·13	6·62	7·41	12·71	6·71	8·04	0·97	5·43	2·55	76·51

ANNUAL RAINFALL COMPARED WITH PREVIOUS YEARS.

Year.	Akwadum.	Nankese.	Koransang	Kukua.	Adonkwanta
1945	52·3	—	—	—	—
1946	44·07	39·98	42·53	45·84	45·01
1947	53·17	50·74	63·98	56·64	68·41
1948	52·68	36·53	46·20	49·19	64·31
1949	56·01	57·62	70·04	70·46	76·51
Mean ...	51·65	46·22	55·69	55·53	63·56

APPENDIX II.

PUBLICATIONS.

Goodall, D. W.	Virus Diseases of Cacao in West Africa. IV. Effect of Virus Infection on the Growth and Water Content of Cacao Seedlings. Annals of Applied Biology, Vol. 36, No. 4. 1949.
Goodall, D. W.	Growth Analysis of Cacao Seedlings. Annals of Botany, Vol. XIV, No. 54. 1950.
Posnette, A. F.	The Pollination of Cacao in the Gold Coast. Journal of Horticultural Science, Vol. XXV, No. 3. 1950.
Greenwood, M. and Posnette, A. F. ...	The Growth Flushes of Cacao. Journal of Horticultural Science, Vol. XXV, No. 3, 1950.
Nicol, J., Owen, H. and Strickland, A. H.	Biological Control of the Mealybug Vectors of Swollen Shoot Virus of Cacao. Nature, Vol. 165, p. 490, March 25th, 1950.
Posnette, A. F. Robertson, N. F. and Todd, J. McA.	Virus Diseases of Cacao in West Africa. V. Alternative Host Plants. Annals of Applied Biology, Vol. 37, No. 2, 1950.
Goodall, D. W.	Studies in the Diagnosis of Mineral Deficiency. V. Manganese Deficiency in Wheat. Annals of Applied Biology, Vol. 36, No. 1, 1949.

APPENDIX III.

FINANCIAL STATEMENT, 1949–50.

LIABILITIES.	£ s. d.	£ s. d.
SURPLUS AND DEFICIT ACCOUNT :—		
Surplus		1,655,286 12 1
DEPRECIATION FUND :—		
Motor Vehicles	1,349 1 3	
General Equipment	906 5 11	
		2,255 7 2
		£1,657,541 19 3

ASSETS.	£ s. d.	£ s. d.
BUILDINGS :—		
Value as at 31st March, 1949	145,423 0 0	
Additions during the year	80,852 18 7	
	226,275 18 7	
Less : Amounts written off	226,275 18 7	
		—
FURNITURE AND EQUIPMENT :—		
Value as at 31st March, 1949	20,688 0 0	
Additions less sales during the year ...	2,292 2 8	
	22,980 2 8	
Less : Amounts written off	22,980 2 8	
		—
SUNDRY DEBTORS :—		
Staff Advances	4,030 16 9	
Staff Subsidies...	764 7 6	
Gold Coast Government	545 0 0	
		5,340 4 3
STORES AT COST :—		
Timber	634 13 6	
Construction	936 15 3	
General	347 14 8	
		1,919 3 5
INVESTMENTS AT COST :—		
(Market value £1,480,871 19s. 5d.) ...		1,609,510 2 9
POST OFFICE SAVINGS BANK DEPOSIT		2,255 7 2
CASH :—		
In Hand—Imprest Account	200 0 0	
Bank of British West Africa Limited ...	9,509 9 2	
Westminster Bank Ltd.—Deposit	28,000 0 0	
Crown Agents for the Colonies	807 12 6	
		38,517 1 8
		£1,657,541 19 3

SGD. ALAN PICKLES.
AG. DIRECTOR OF CACAO RESEARCH.

We have audited the above Balance Sheet of the West African Cacao Research Institute with the books and vouchers of the Institute and have obtained all the information and explanations that we have required. In our opinion and subject to our Report of even date attached hereto this Balance Sheet sets forth a true and correct view of the financial position of the Institute as at 31st March, 1950, according to the best of our information and the explanations given to us and as shown by the books of the Institute.

KUMASI,
20th June, 1950

SGD. CASSLETON ELLIOTT & CO.,
Auditors.

Waterlow & Sons Limited, London & Dunstable.